Ecological Niche Modeling and Environmental Forecasting Using Remotely Sensed Data and A Genetic Algorithm

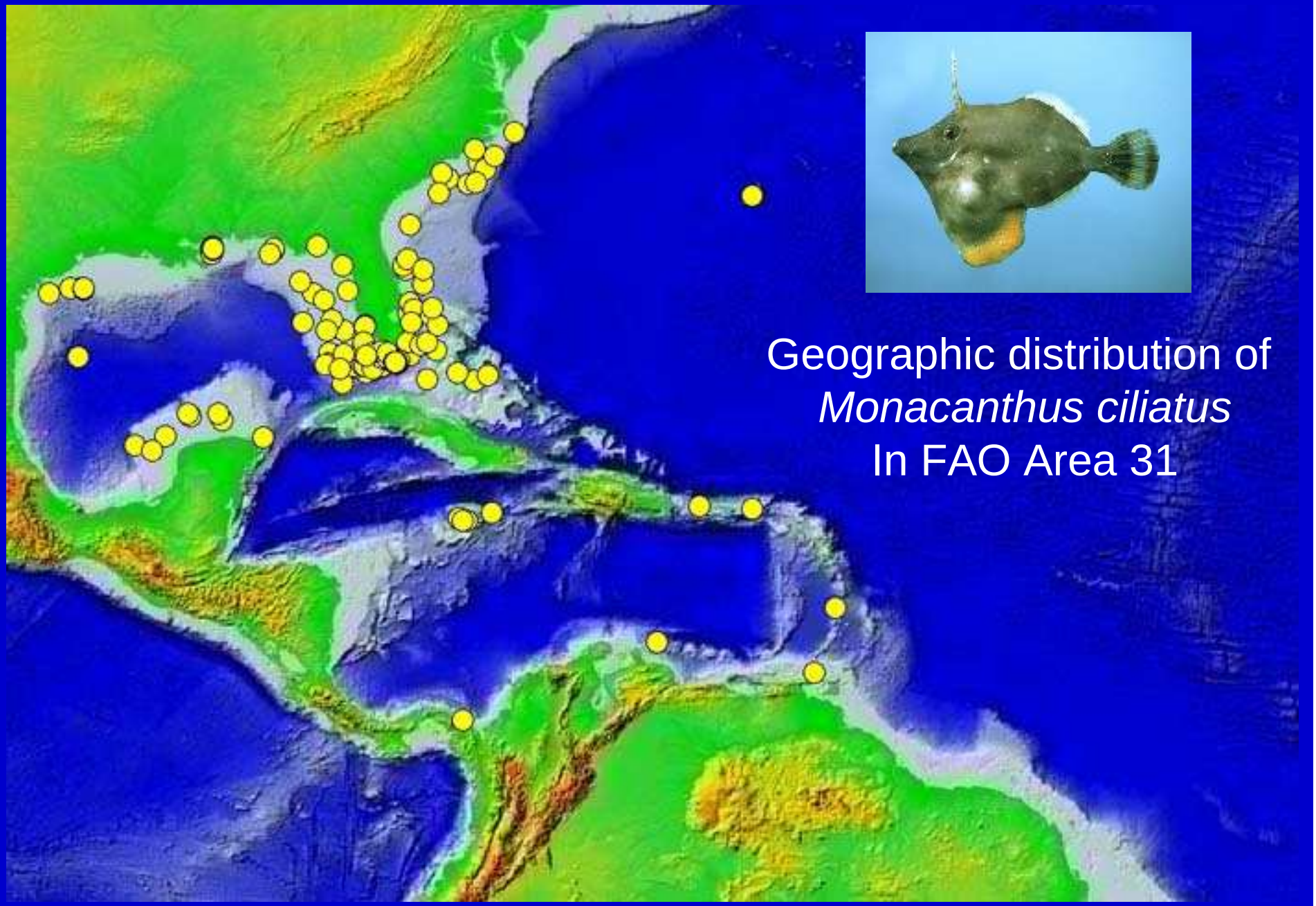
AIS Research Group

Dept. of Ecology and Evolutionary Biology

Biodiversity Research Center

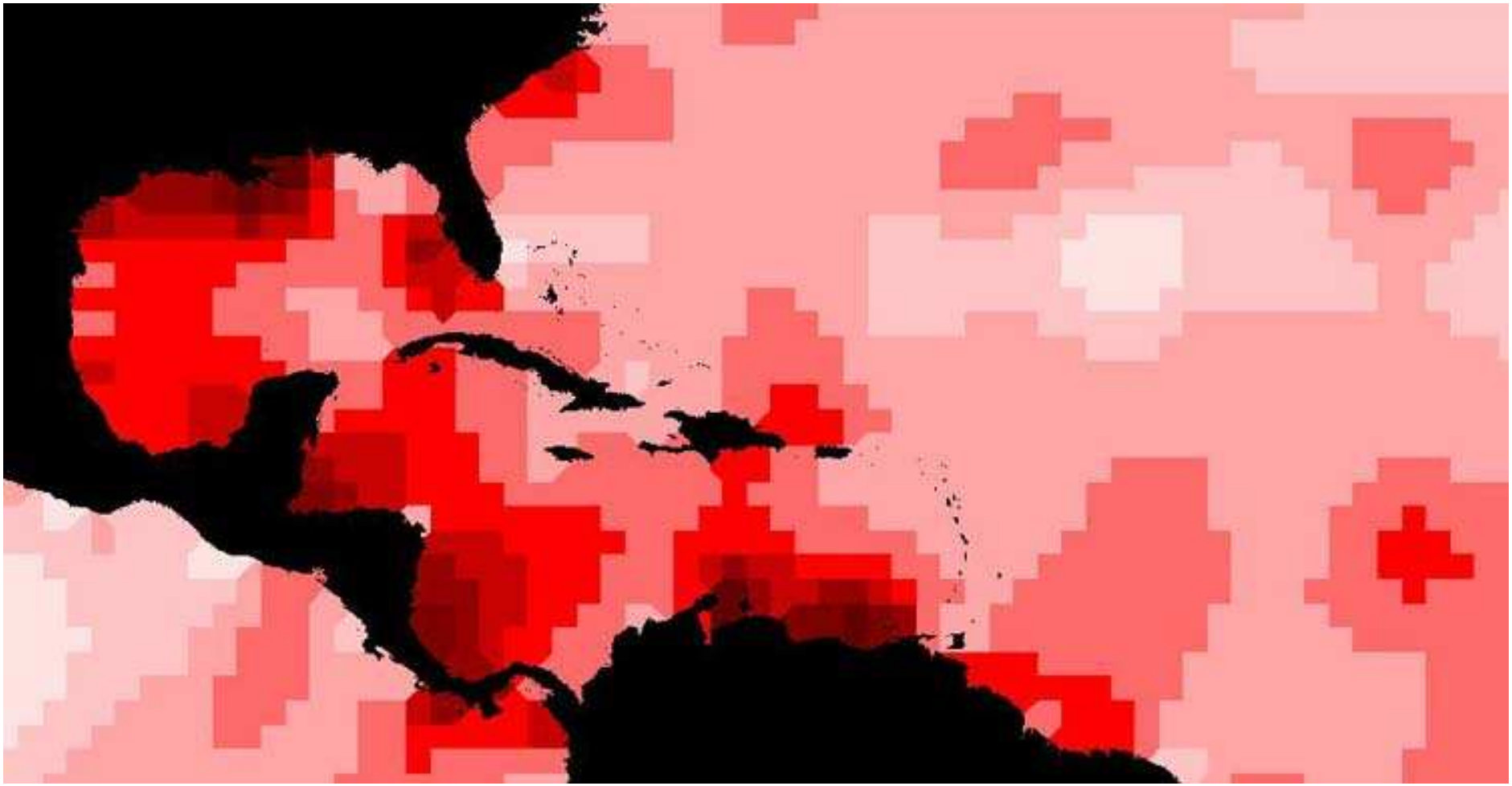
University of Kansas


C. idella
Chaetodon lunula
Carp kissing
Channa argus
C. carpio
Pterois volitans
photo by Paula Whitfield (NOAA Beaufort Laboratory)
S. lucioperca
Mylopharyogodon piceus



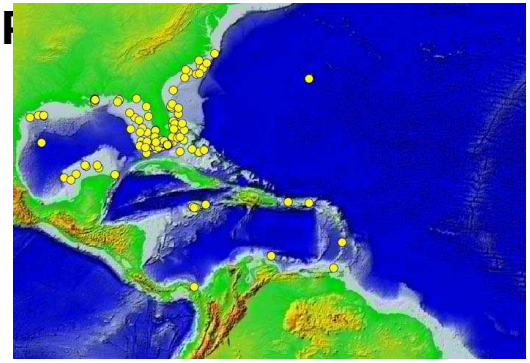
Geographic distribution of
Monacanthus ciliatus
In FAO Area 31

Global Environmental Data WOA

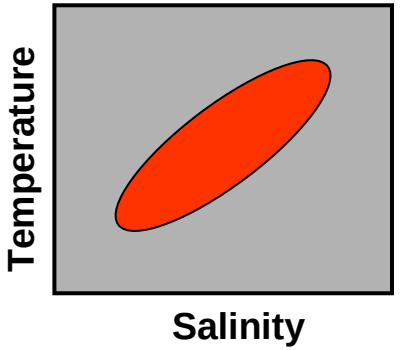


Ecological Niche Modeling and Biogeography - Overview

Distributional

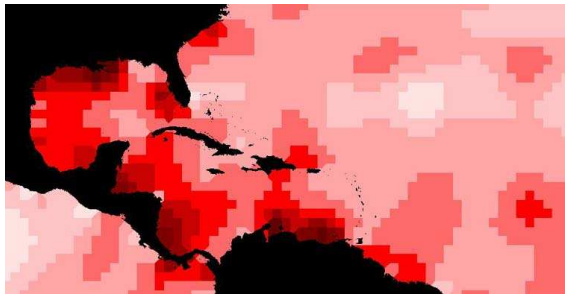


Ecological niche model

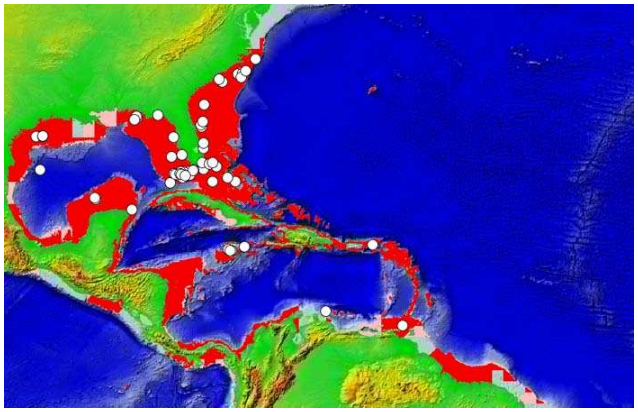


Project onto geography

GARP



Ecological variables



Distributional prediction

Environmental GIS

Specimen Records

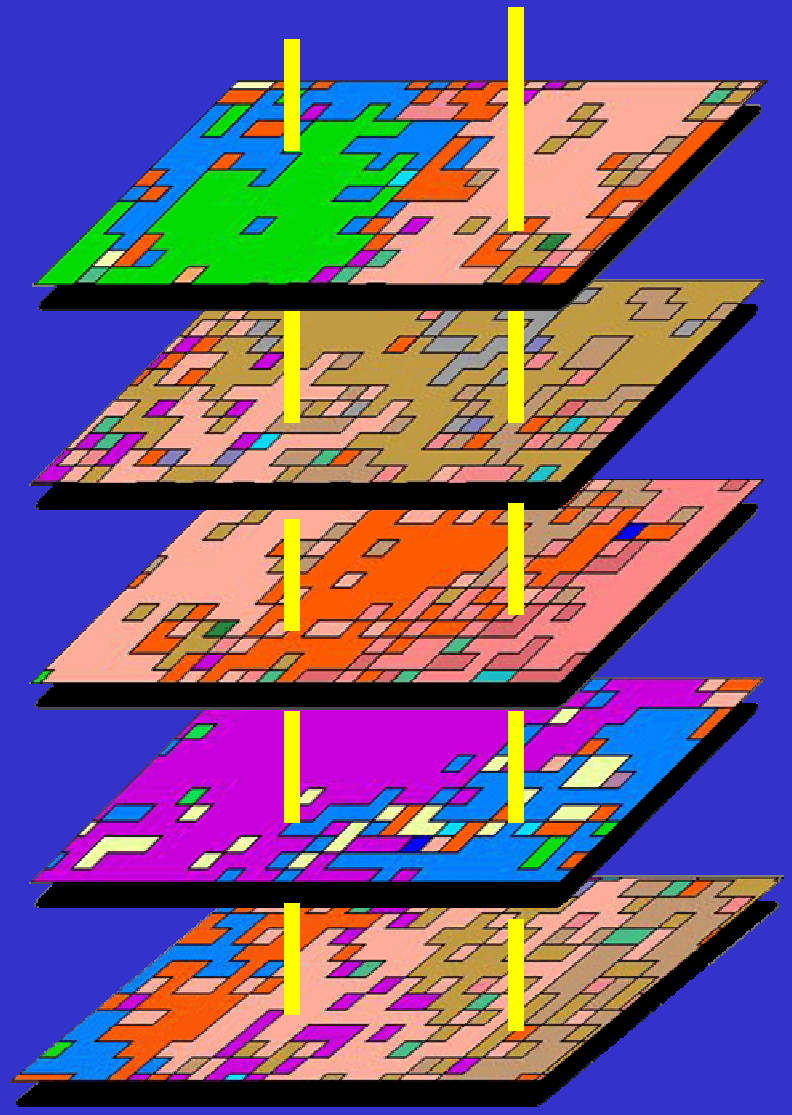
Temperature

Salinity

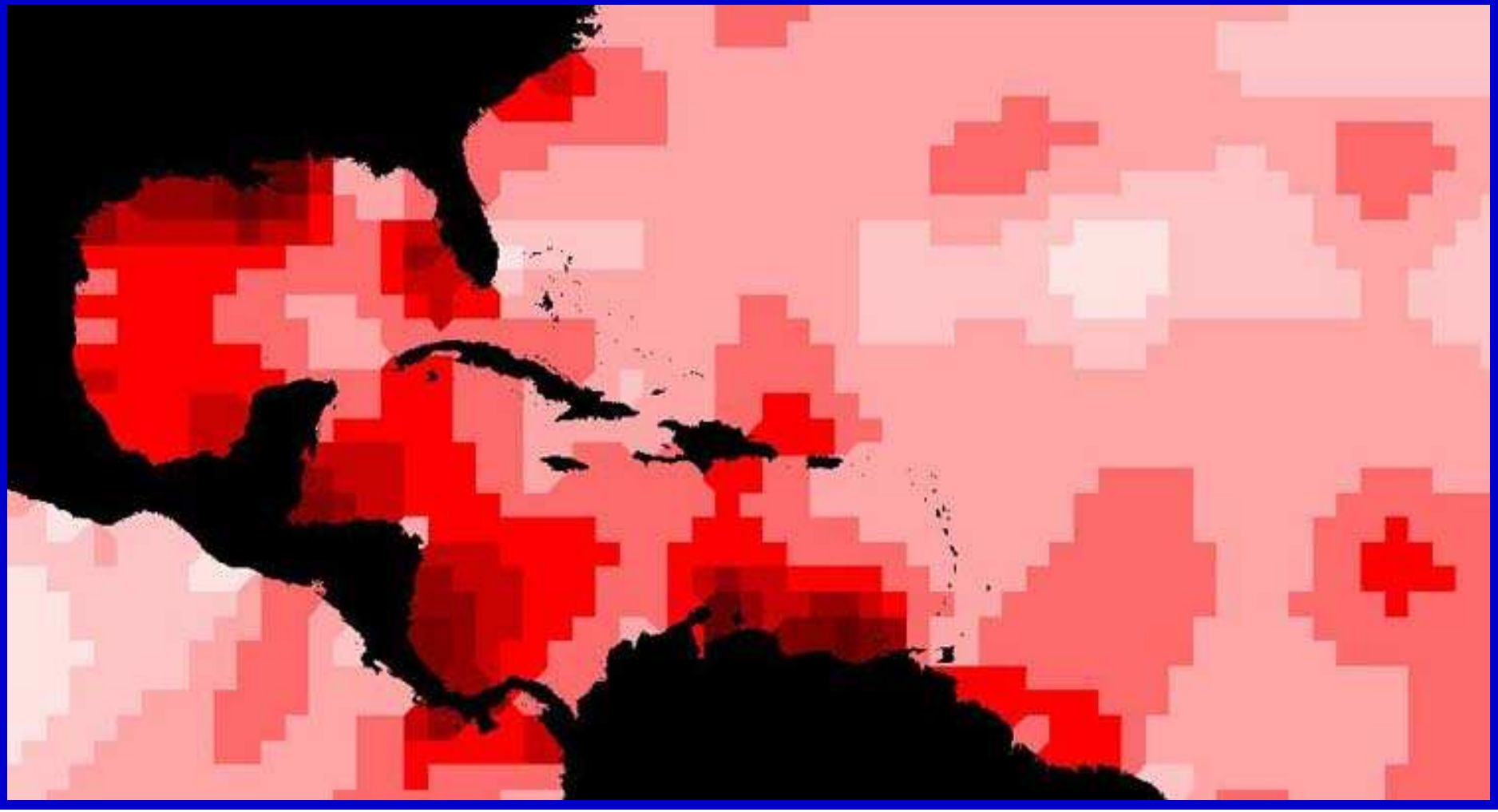
Bathymetry

Dissolved Oxygen

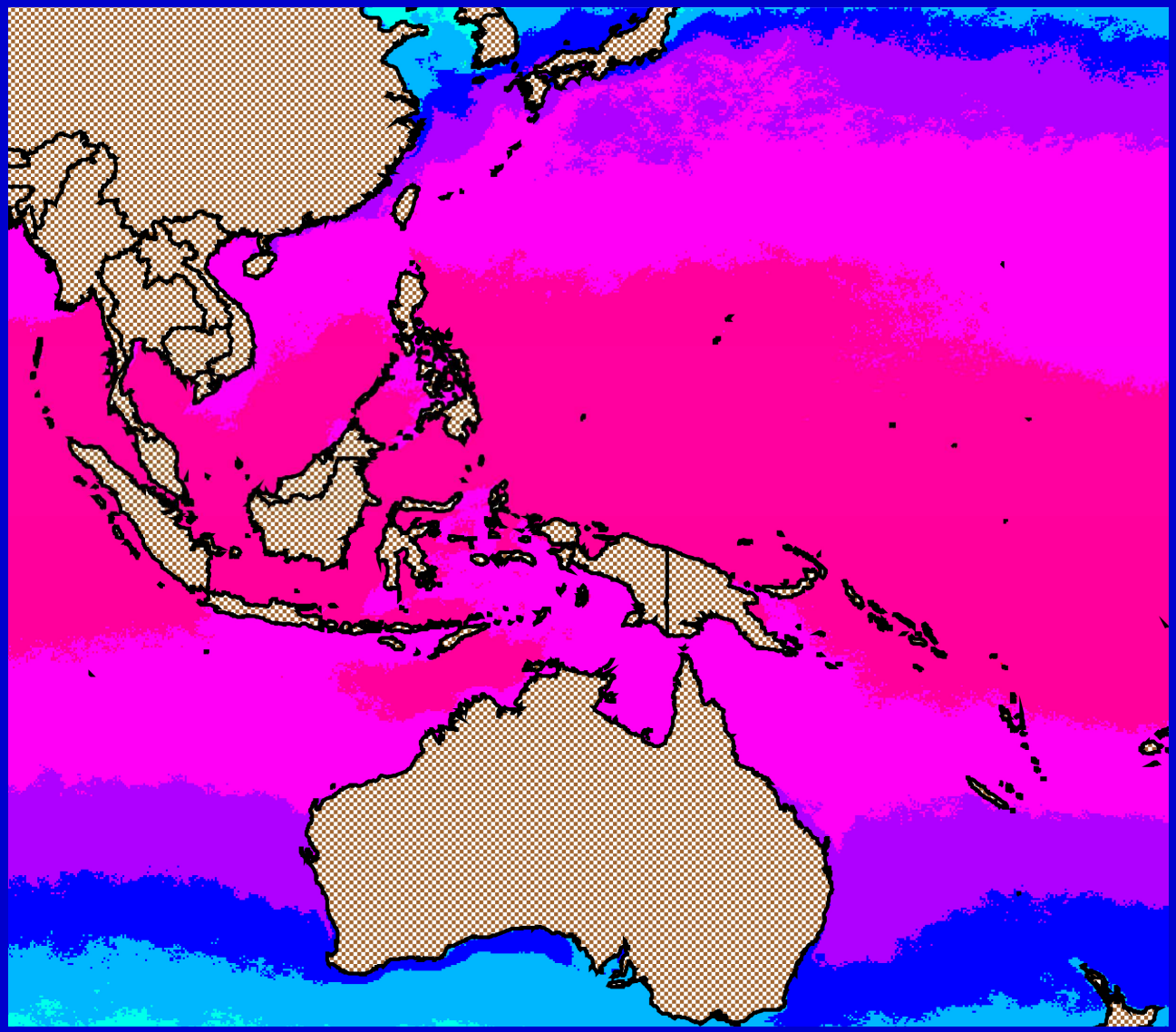
Nitrates



Global Environmental Data WOA



Global Environmental Data MODIS



Environmental Coverages

World Ocean Atlas (1998) and Bathymetry

- Bathymetry Smith and Sandwell (1997)
- Temperature
- Salinity
- Dissolved oxygen
- Percent oxygen saturation
- Phosphate
- Nitrate
- Silicate
- Chlorophyll
- Apparent oxygen utilization
- Resolution: ca 60 km^2 (equator)

MODIS and Bathymetry

- Bathymetry Smith and Sandwell (1997)
- Sea surface temperature
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Monacanthus ciliatus
Station Data

ROC = 0.9535

se = 0.0029

p < 0.001

Monacanthus ciliatus
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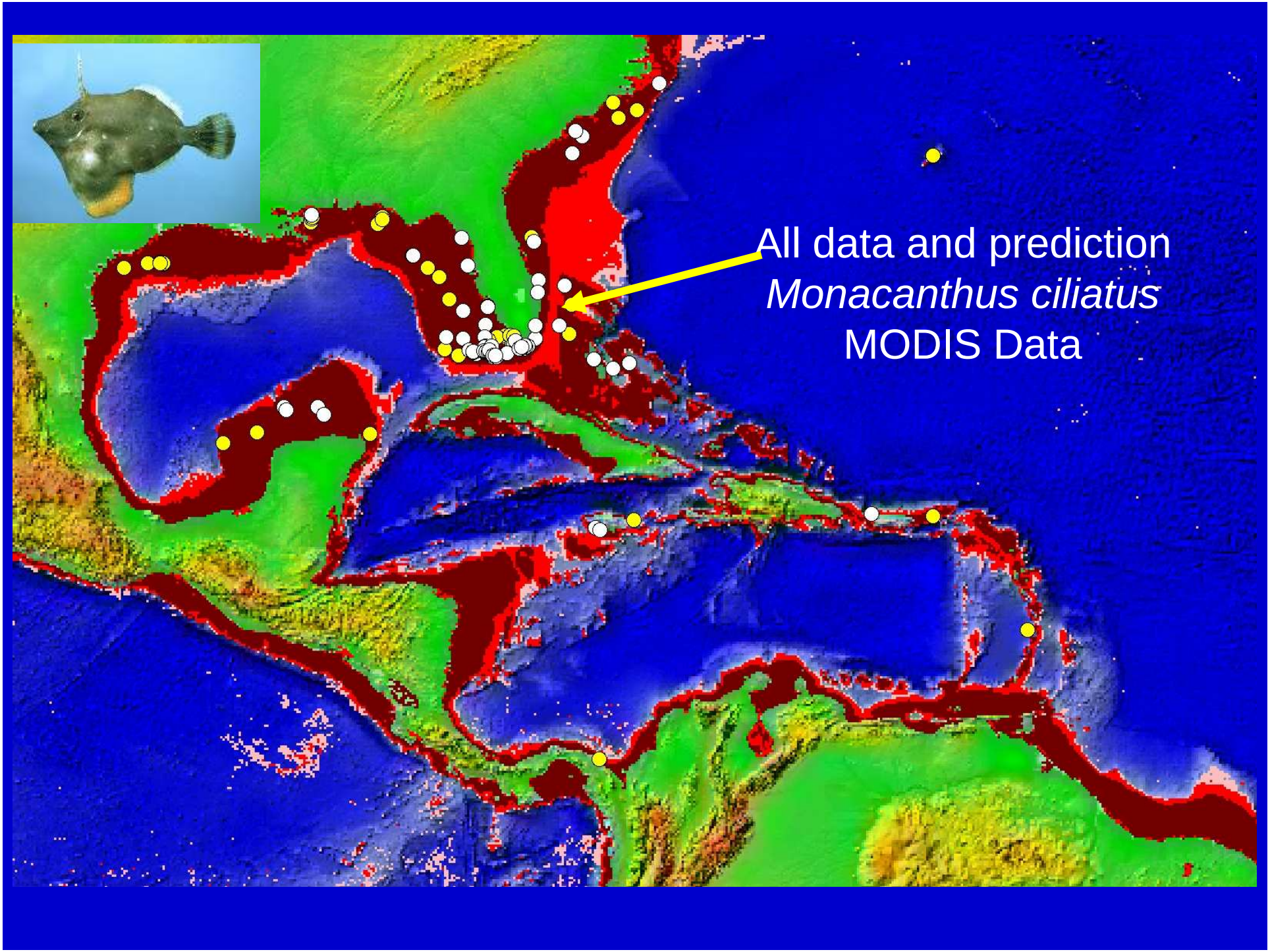
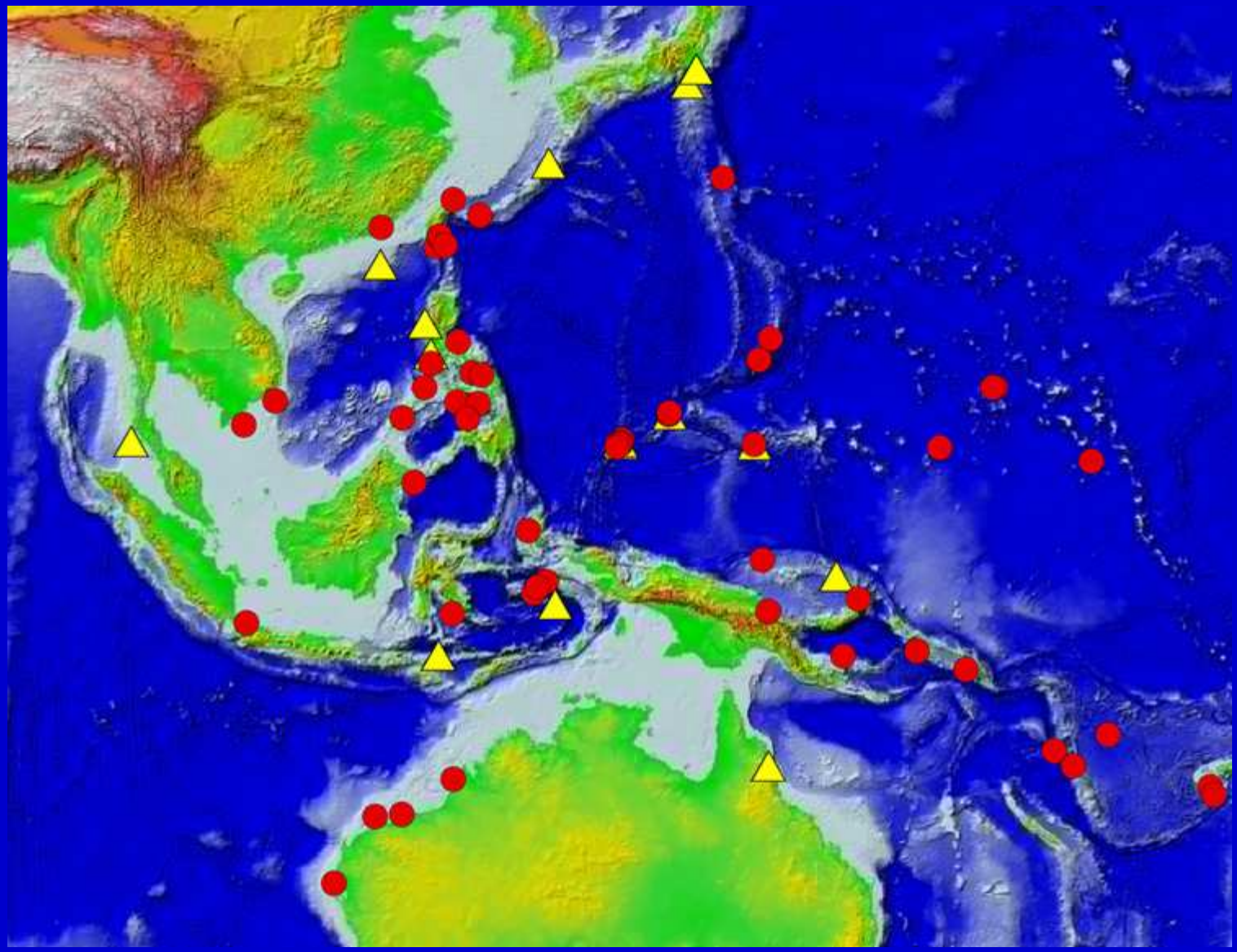

All data and prediction
Monacanthus ciliatus
MODIS Data

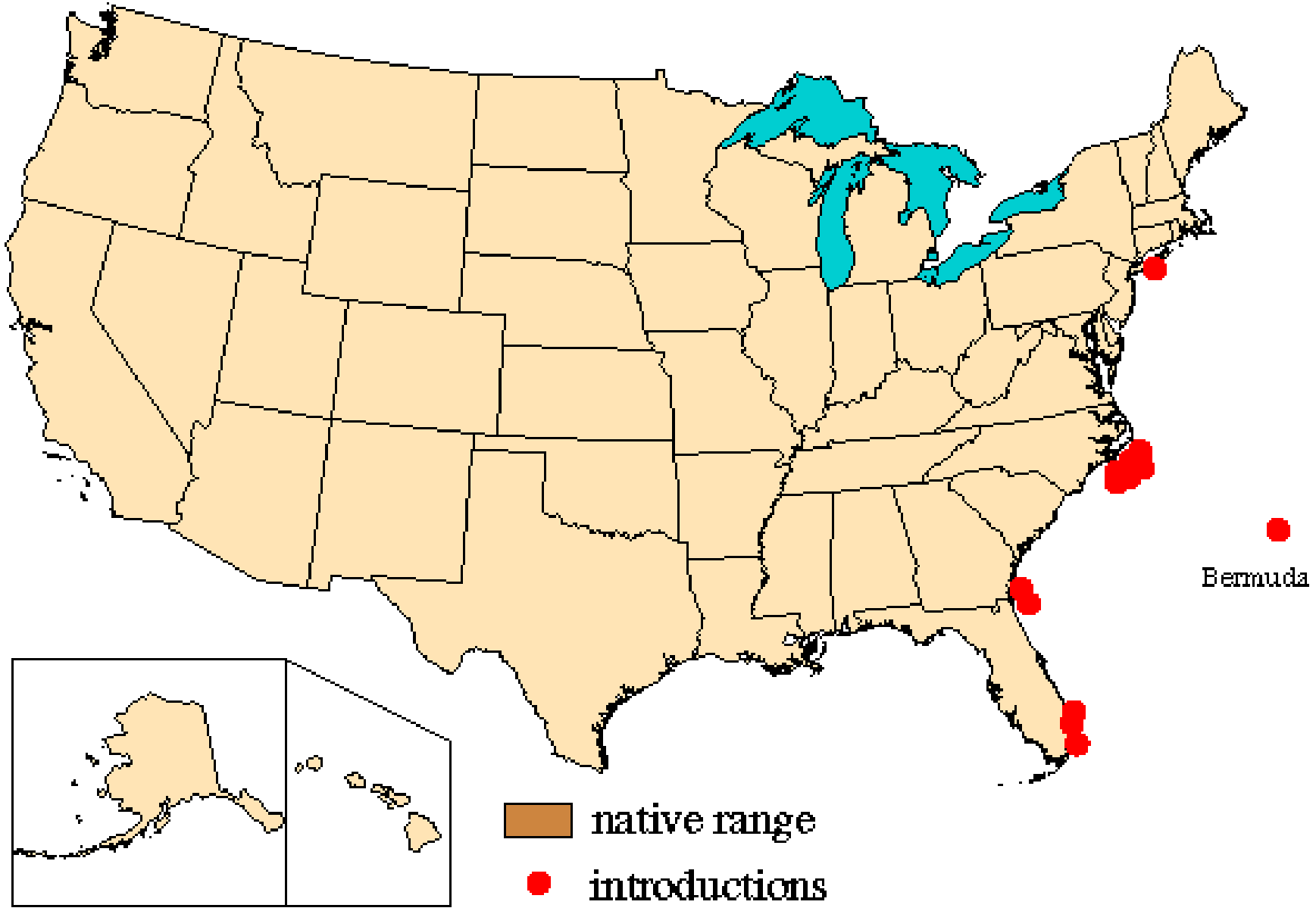
Pterois volitans

Pterois volitans Native Range Data

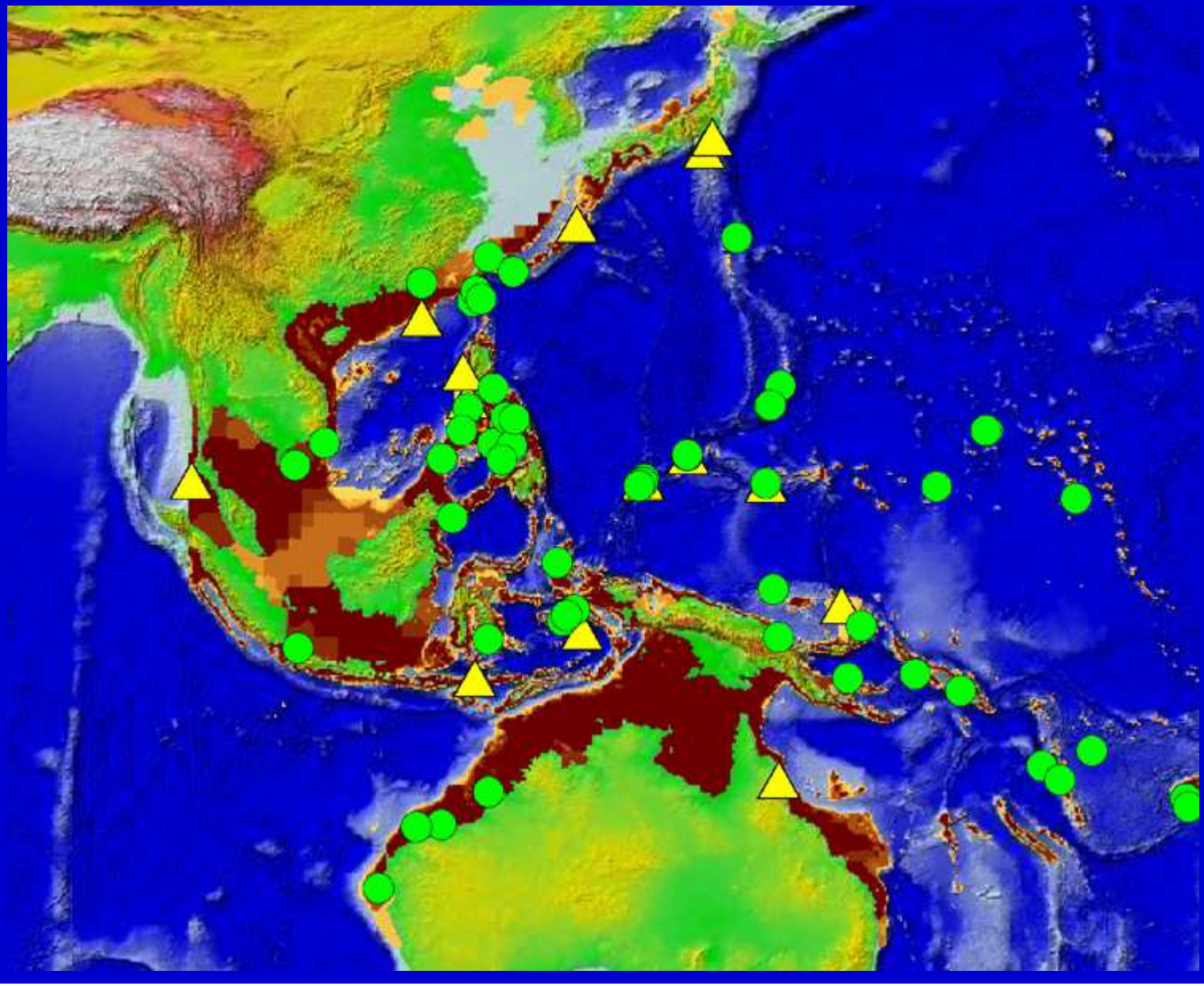


USGS
science for a changing world

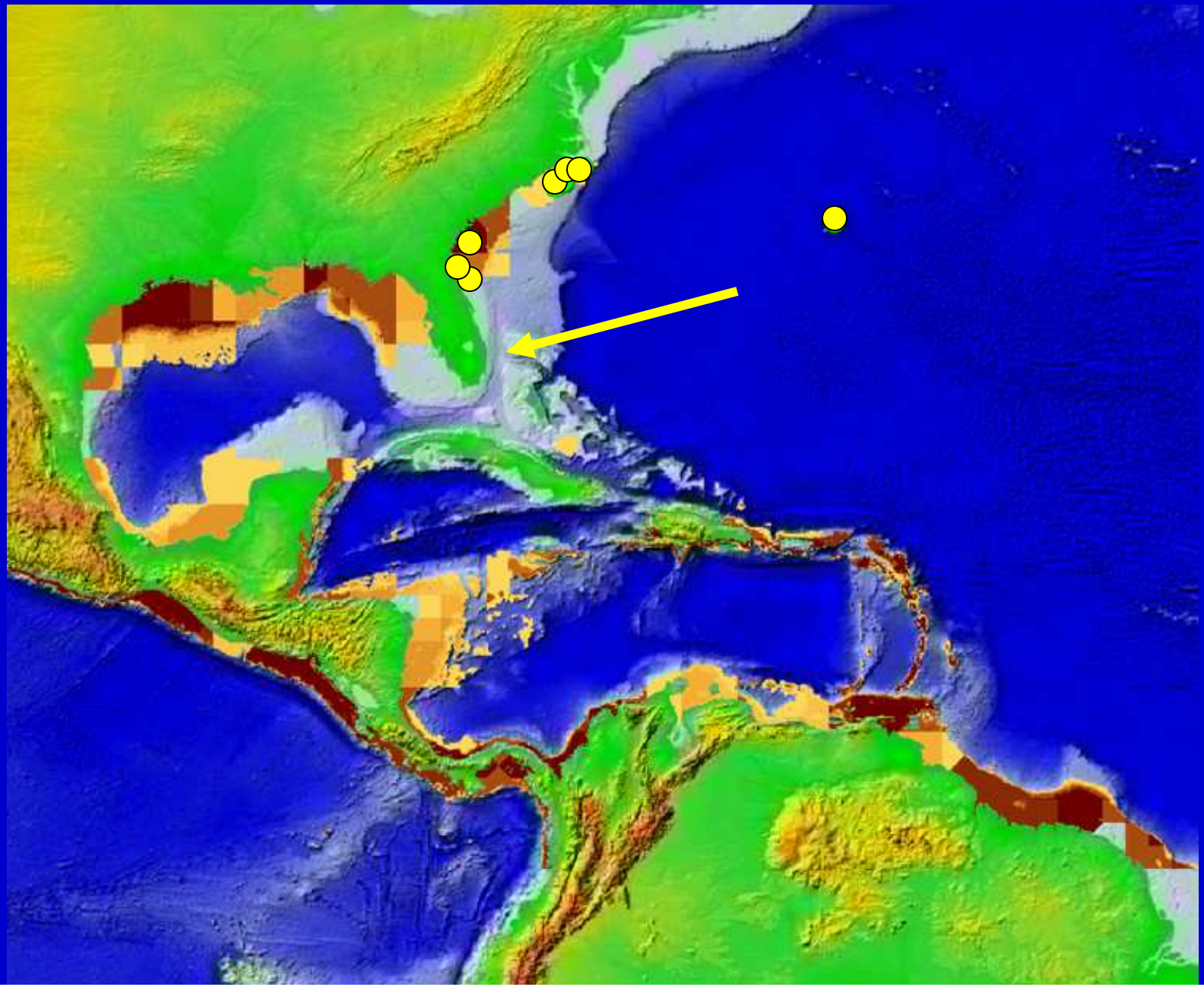
Pterois volitans



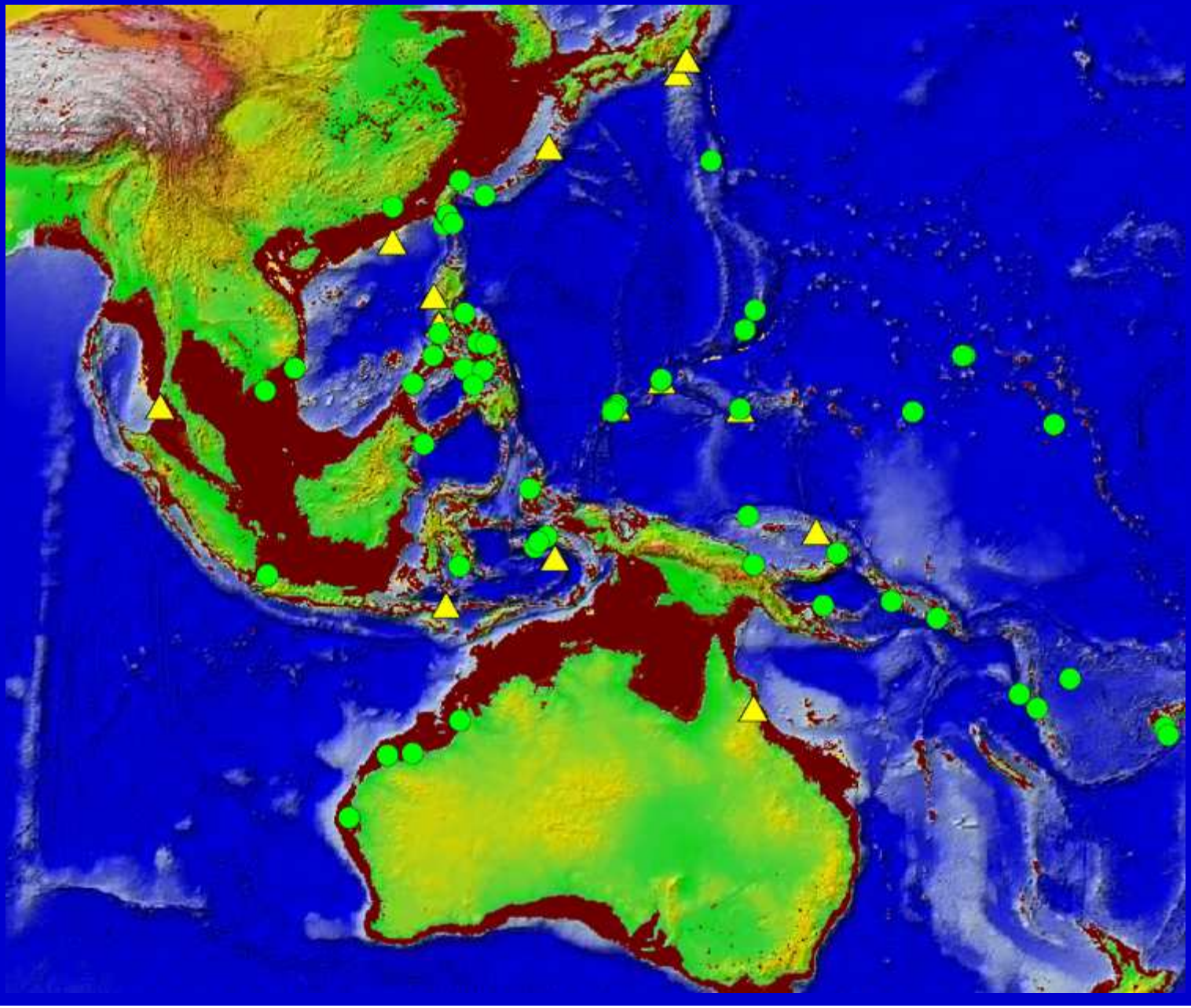
Pterois volitans WOA Native Range



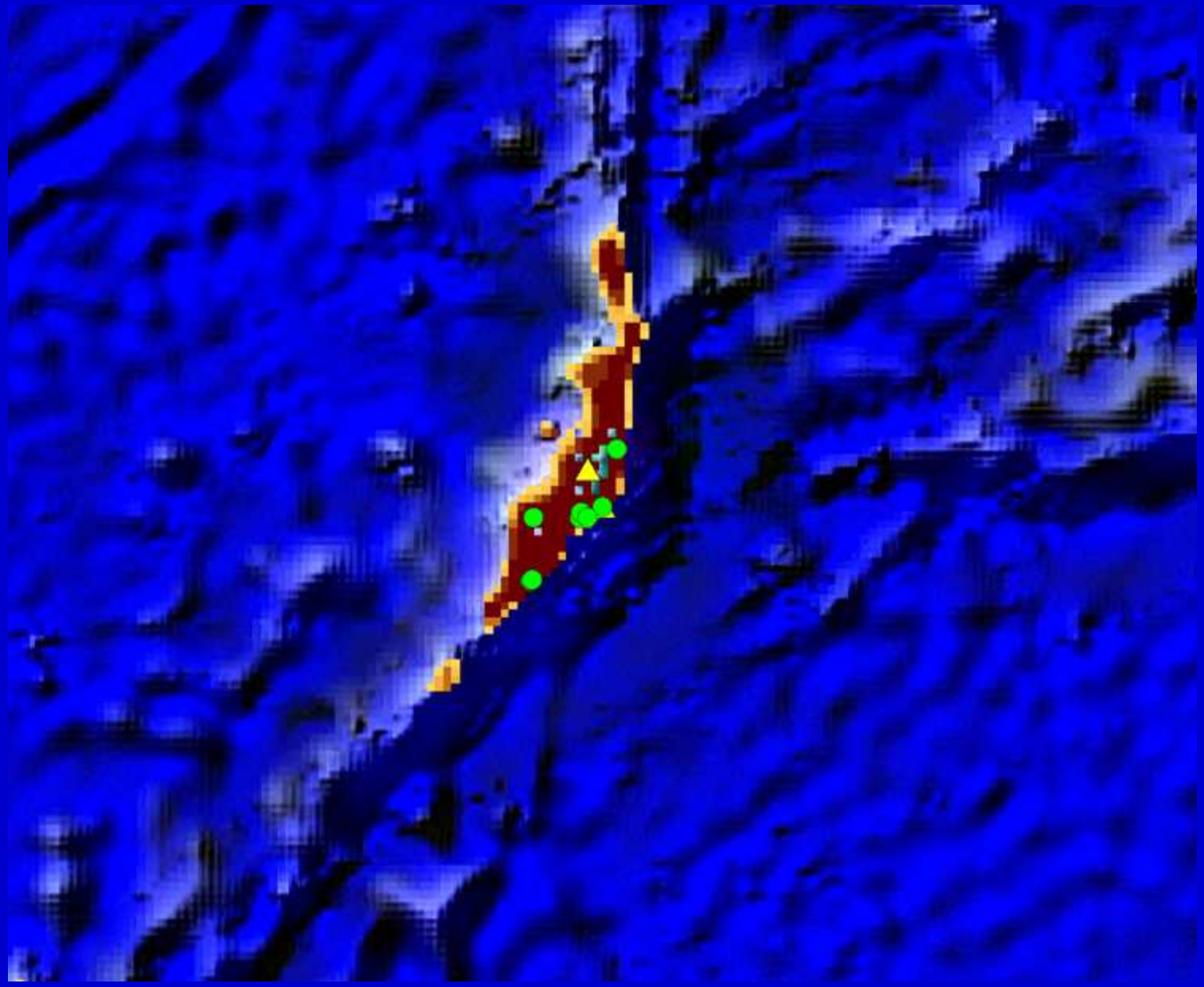
Pterois volitans WOA Data Atlantic



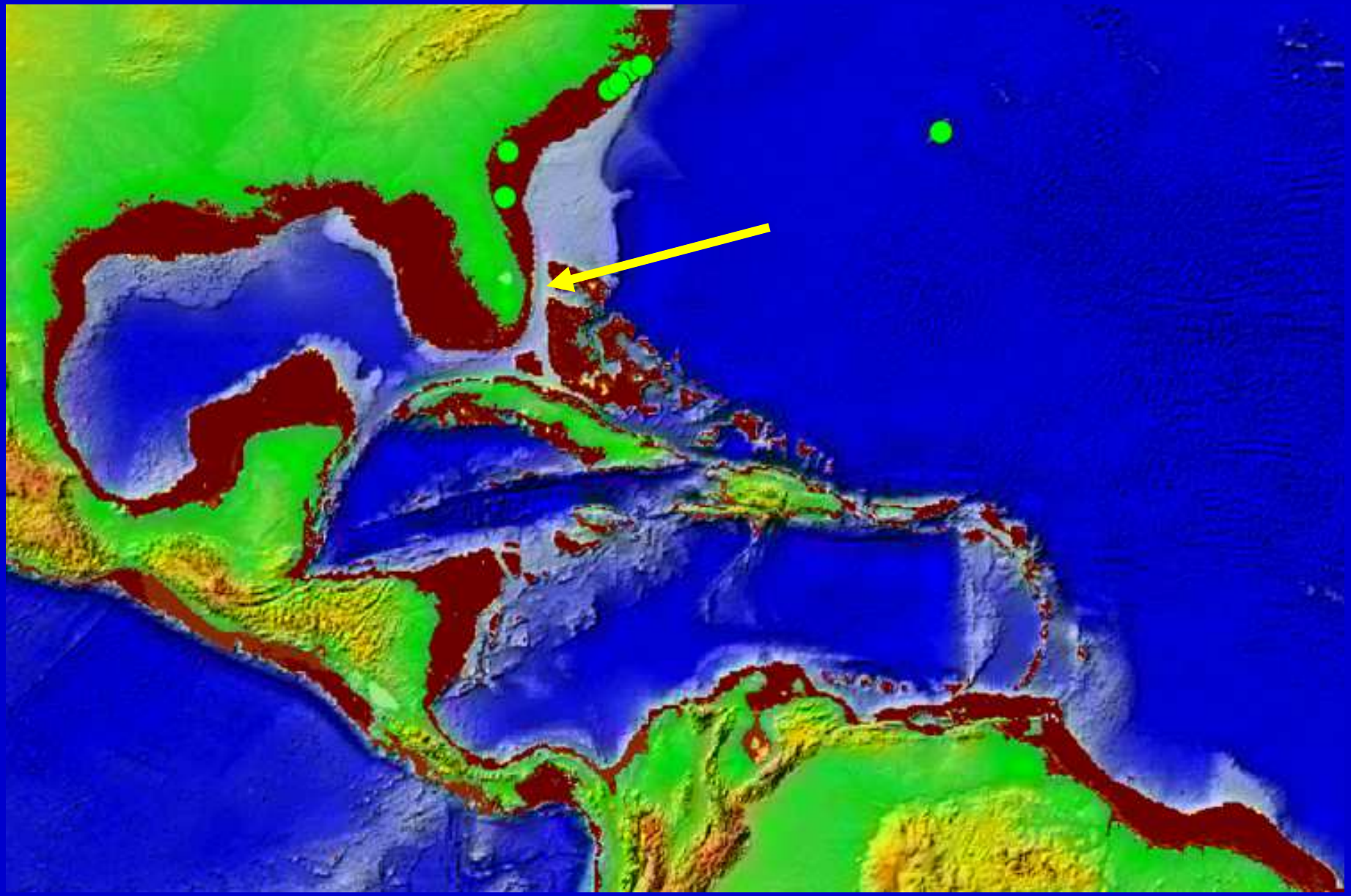
Pterois volitans Modis Native Range



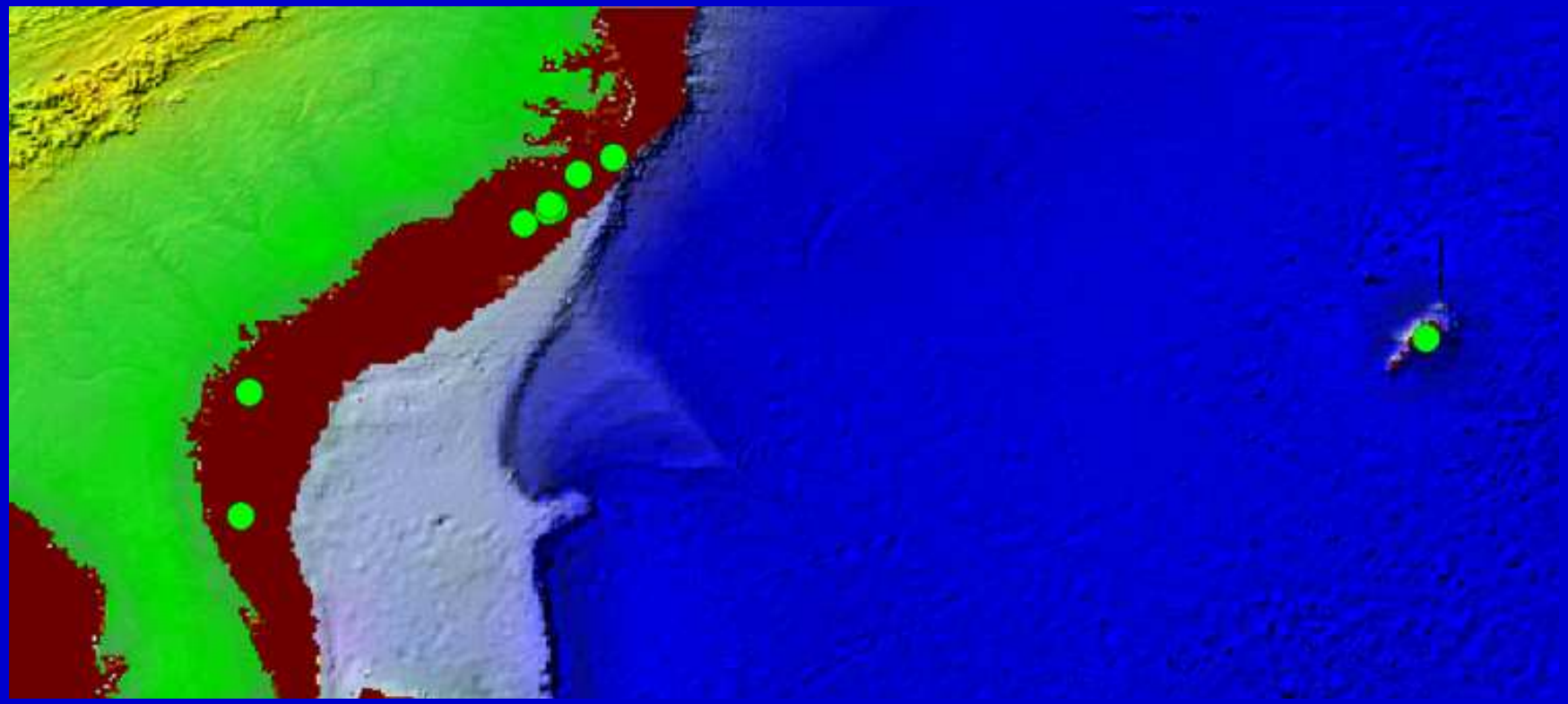
Pterois volitans MODIS Palau Detail



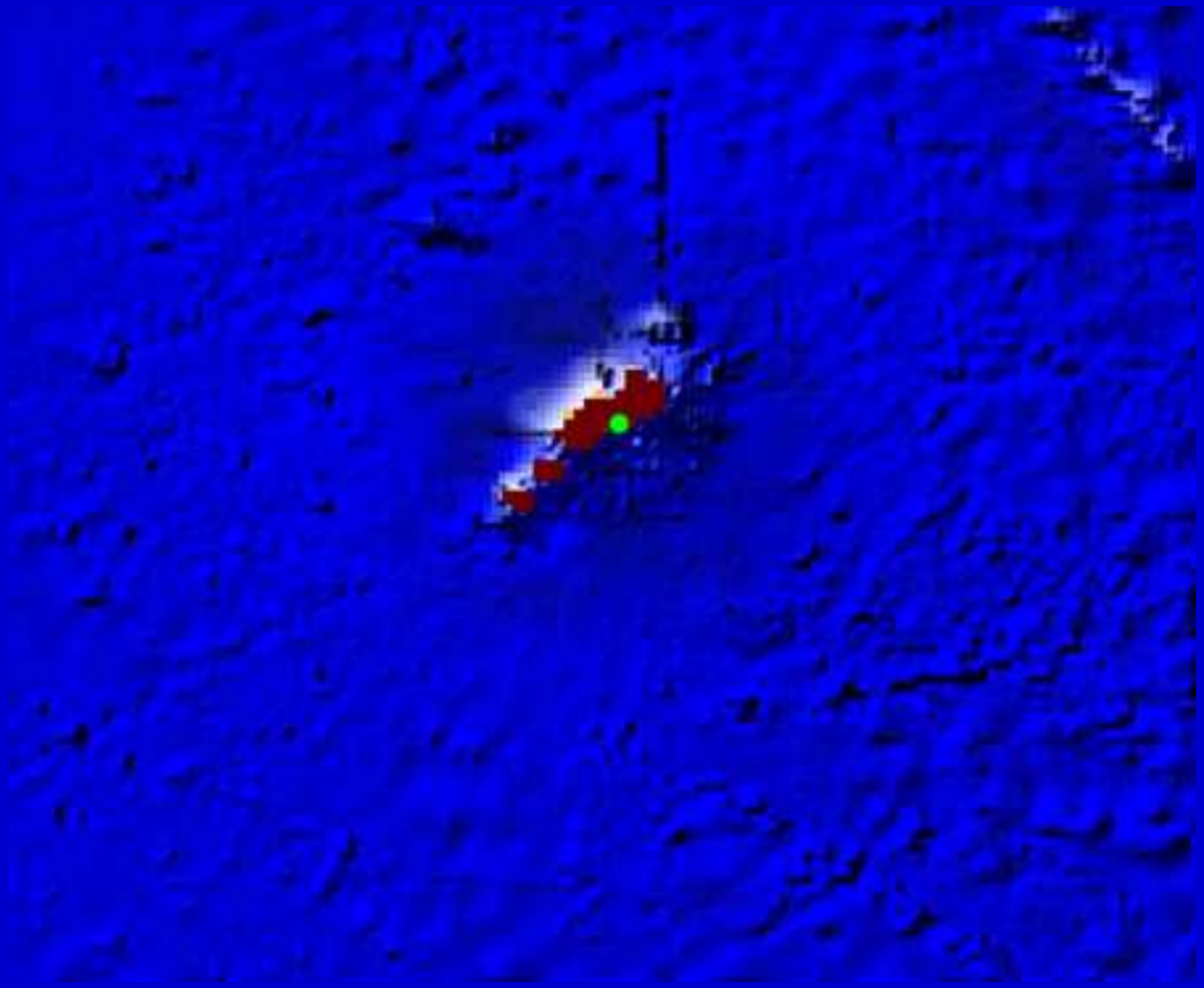
Pterois volitans MODIS Atlantic



Pterois volitans MODIS Atlantic Detail



Pterois volitans MODIS Bermuda



Can We “Postdict” Invasions? Largemouth Basses in Japan

- Players: A consortium of KU and Japanese investigators including Wiley, McNyset, Peterson, Katherine Powers (KU non-thesis masters project on basses), David Vieglais (FishNet), Ricardo Scachetti-Pereira (DeskTop GARP), Kei'ichiro Iguchi (Institute of Fisheries Science, JP), Keiichi Matsuura (National Science Museum, JP), and Taiga Yodo (JP Science and Technology Corporation)

30 Year Averages of:

- Diurnal temperature range
- Ground frost frequency
- Precipitation
- Solar radiation
- Minimum temperature
- Mean temperature
- Wet day frequency
- Maximum temperature
- Vapor pressure

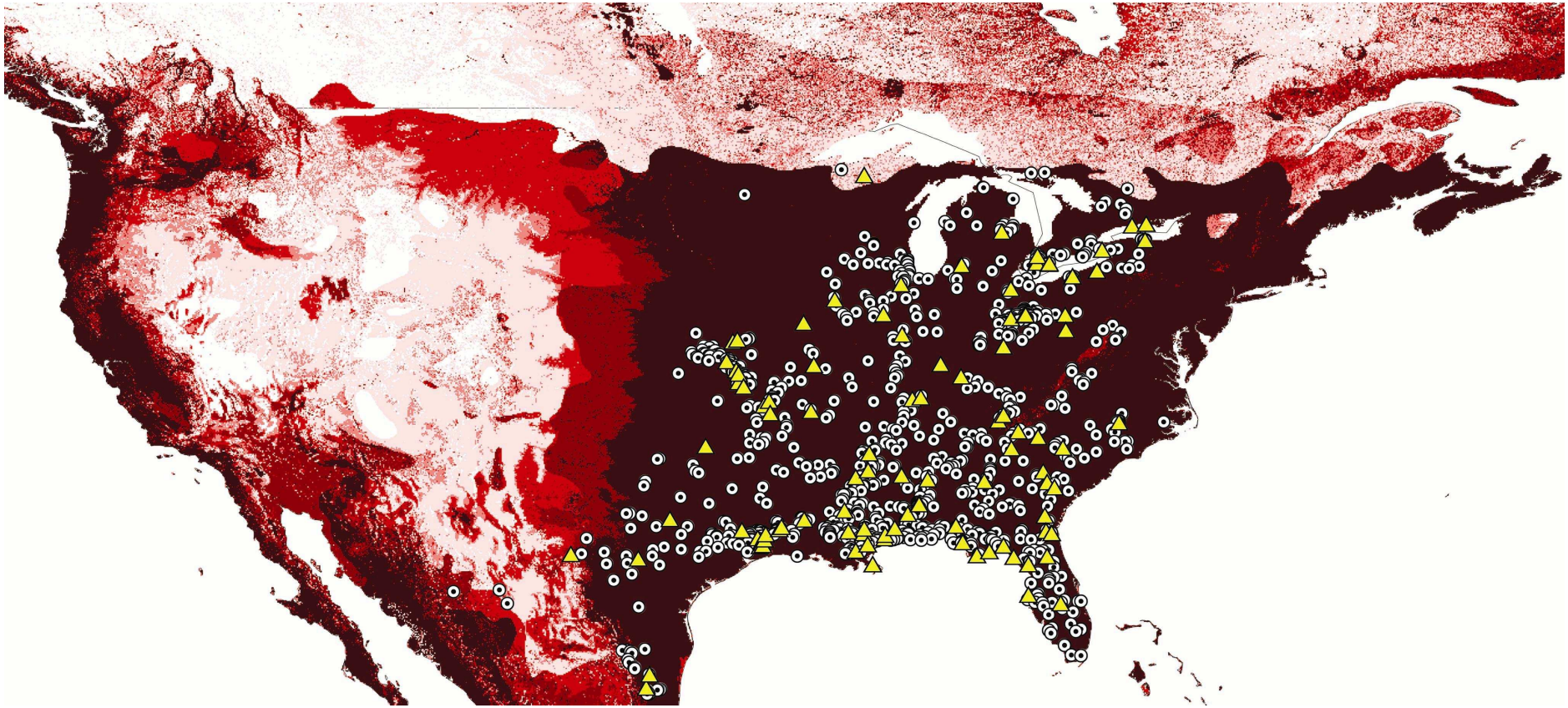
Stream Profiles

- Elevation
- Aspect
- Flow accumulation
- Slope
- Topographic index

Vegetation

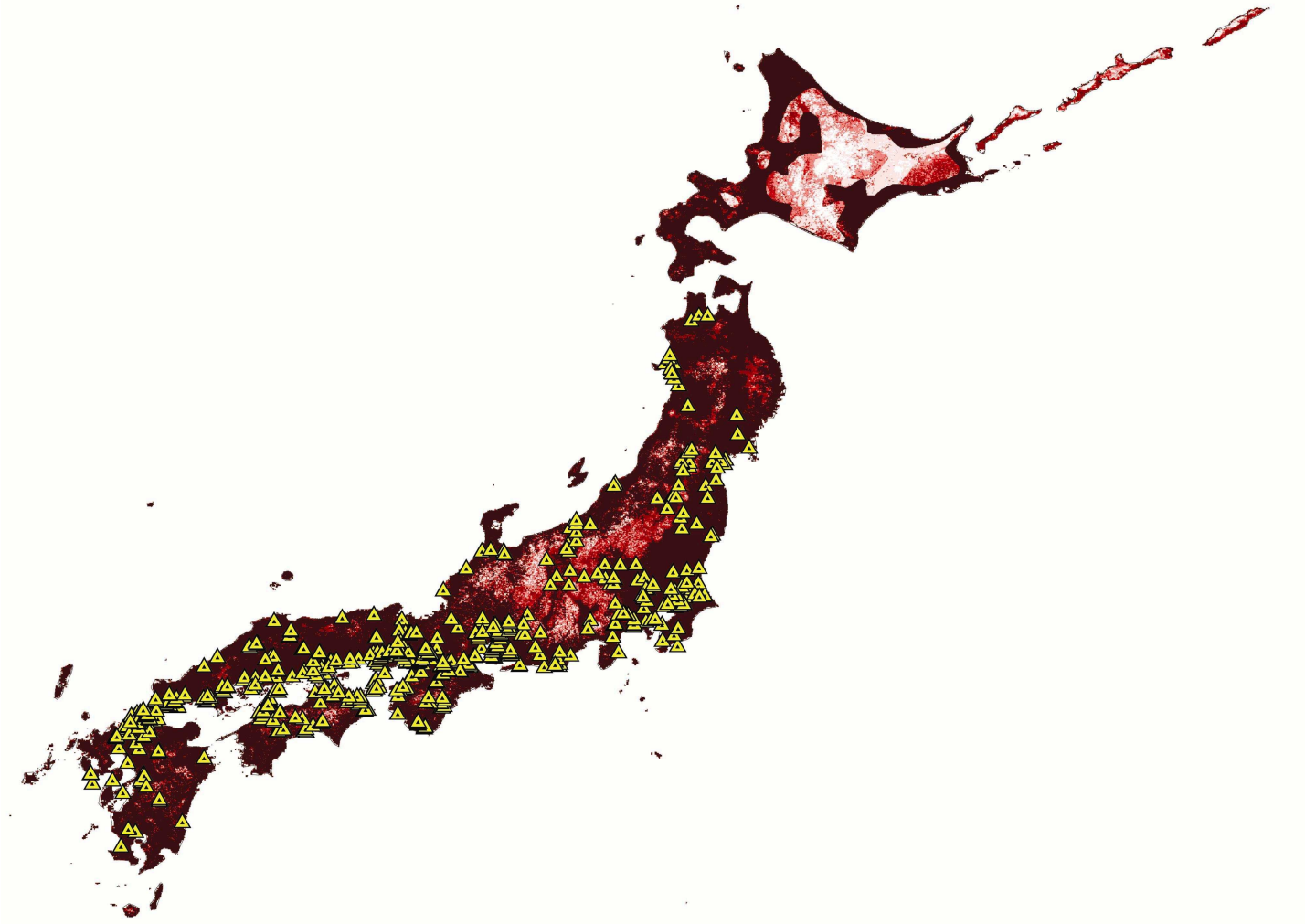
- Percent tree cover

Micropterus salmoides in NA



Native range data and prediction. Circles are localities used to model, triangles are localities used to test the model.

Micropterus salmoides in Japan



Predicted distribution and known introductions in Japan

Conclusions

- GARP modeling yields statistically significant ecological forecasts of species in both the freshwater and marine environments.
- In the marine environment, MODIS coverages perform better than station-based coverages for species in relatively shallow waters.
- GARP yields statistically significant “postdictions” of species invasions and can be used as a proactive tool for accessing invasive threats.

Acknowledgements

Town Peterson, Dick Robins, Kris McNyset, Pingfu Chen, Shannon DeVaney, Richardo Scachetti-Pereira, Aimee Stewart, Katherine Powers

FISHNET Distributed Biodiversity Information System

Office of Naval Research, N00014-00-1-0087

NSF Grant DEB21240

USGS Center for Aquatic Resource Studies

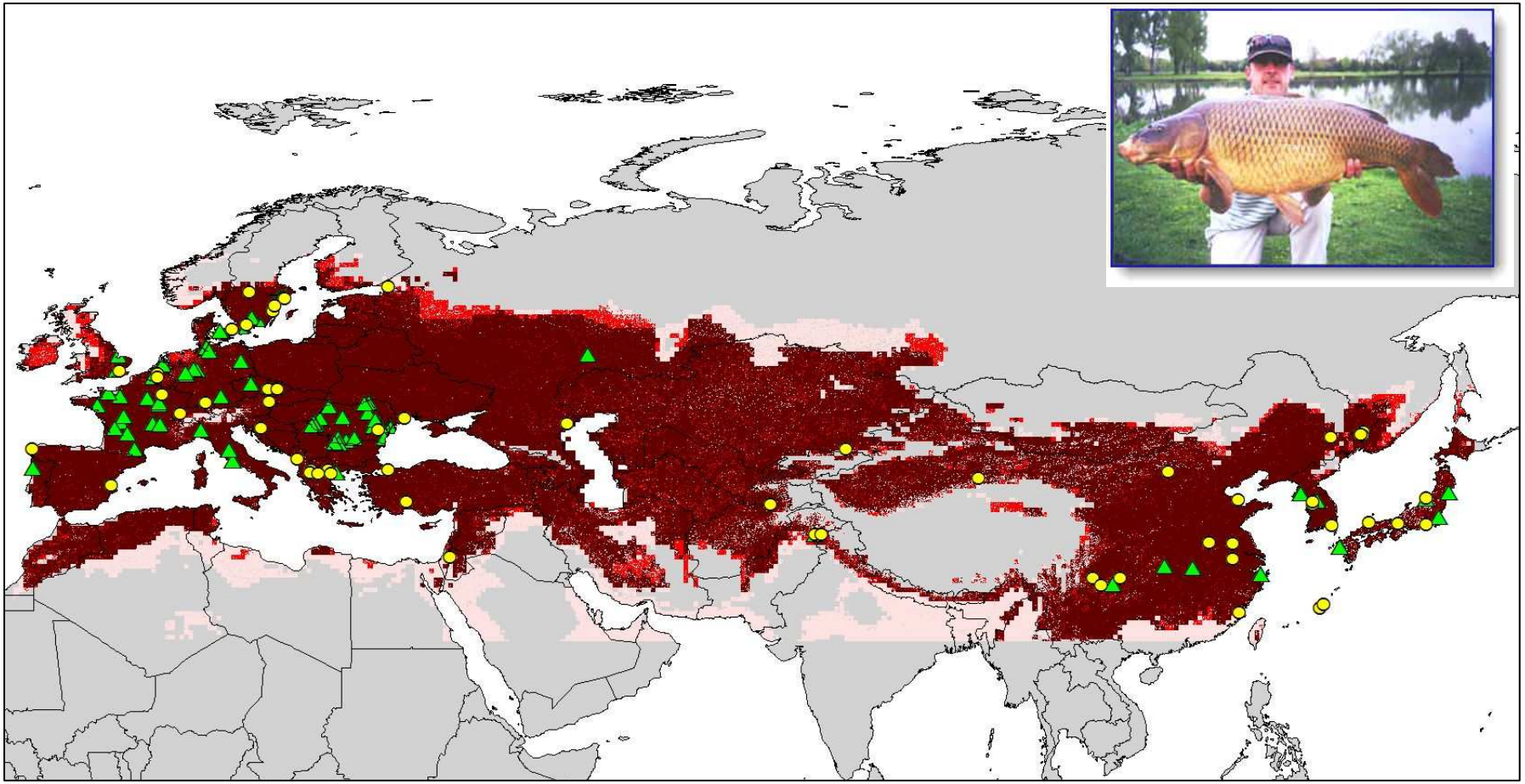
Temperate Invasive Threats

- Project: Model potential invasive species before they invade, or at least before they spread.
- Work carried out in concept with Jim Williams and Walt Courtney, USGS, Gainesville
- KU Players: Pingfu Chen (Asian invasive), Kris McNyset (European invasives) and Ed Wiley

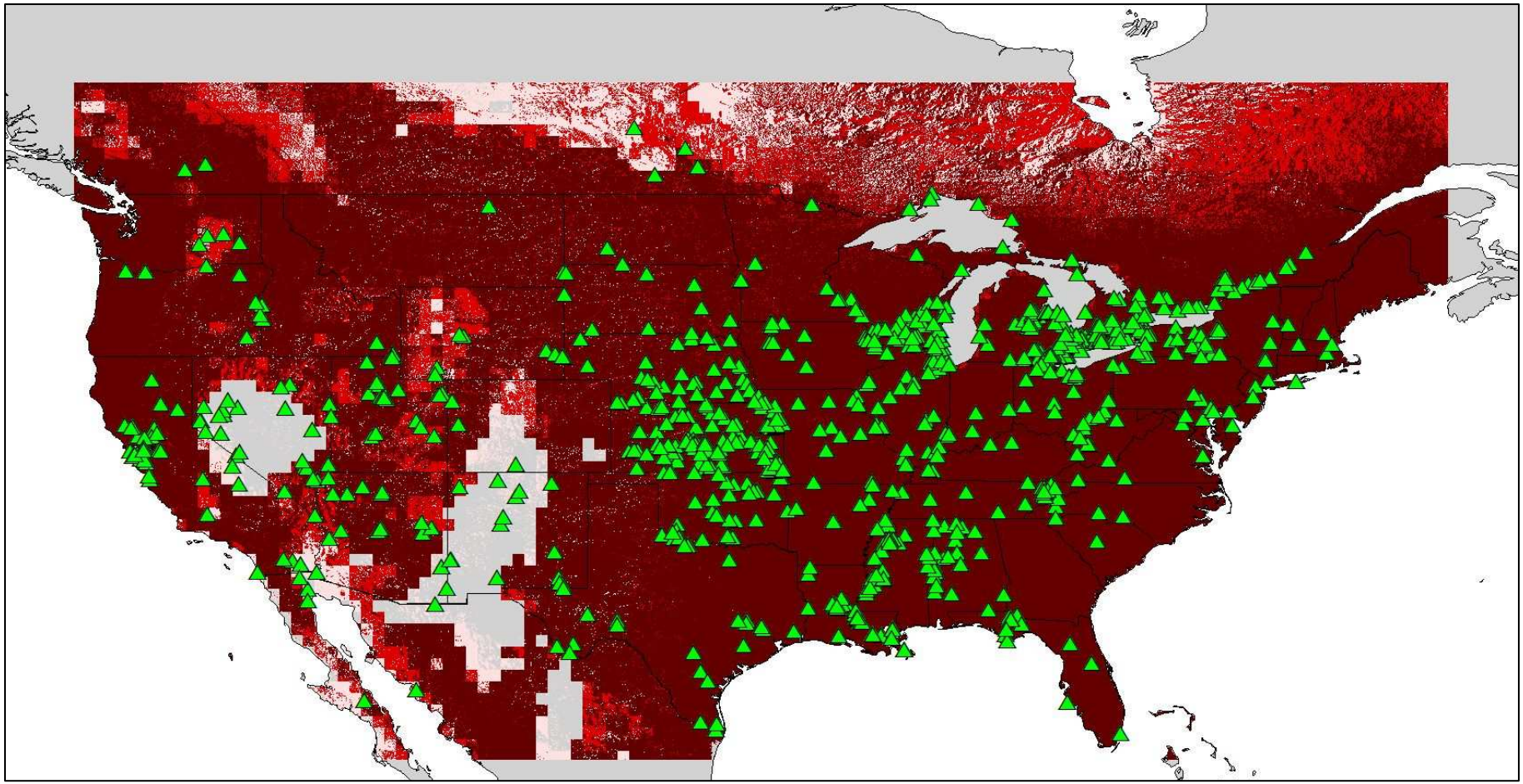
Tale of Three Carps

- One step down the line: Can we project how invasive species might spread.
- Strategy: Find new and old invasive species and compare them.
- Players: Justin Williams (now at Colorado State, undergraduate researcher), Kris McNyset, Shannon Devaney

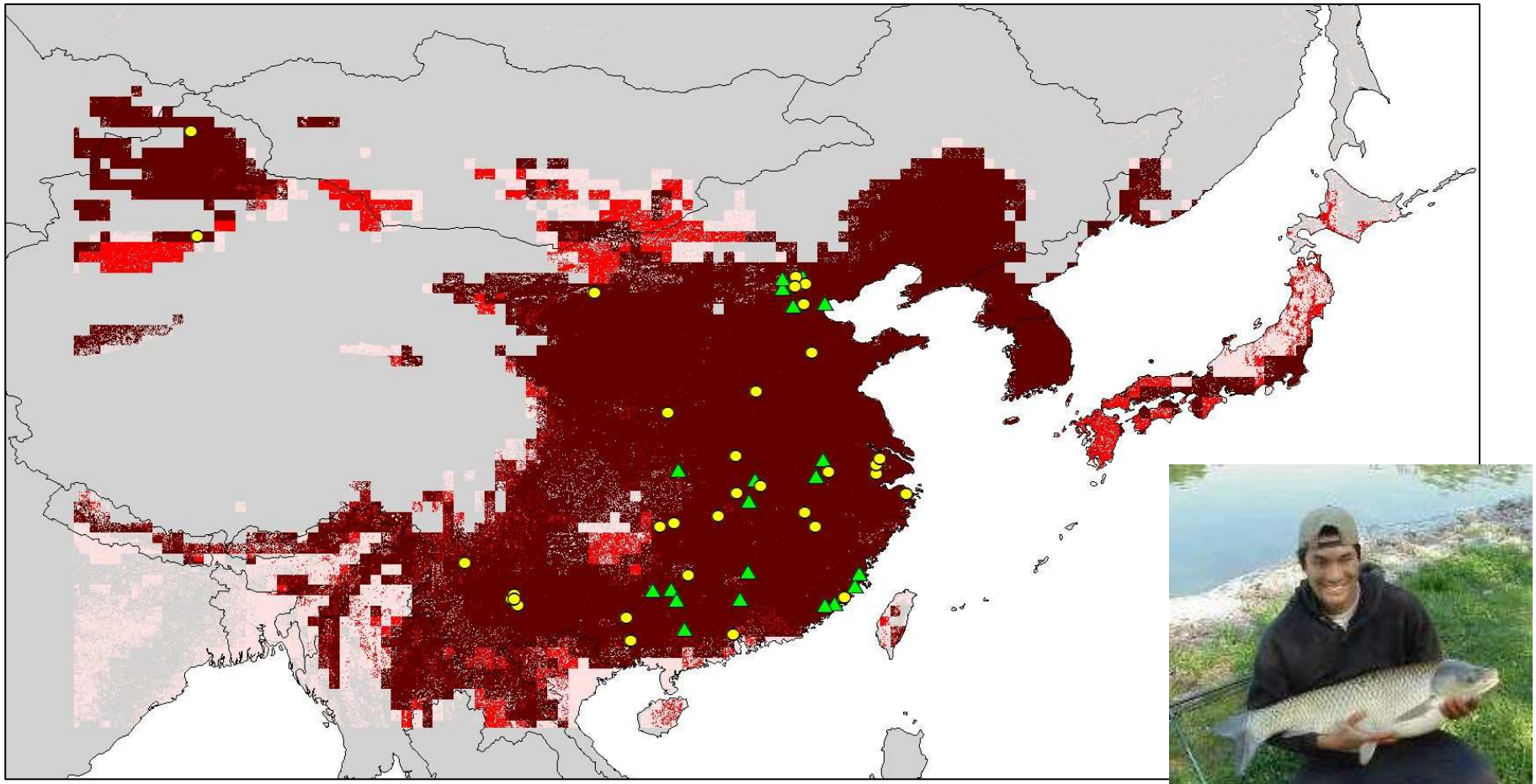
Cyprinus carpio, Native Range Model



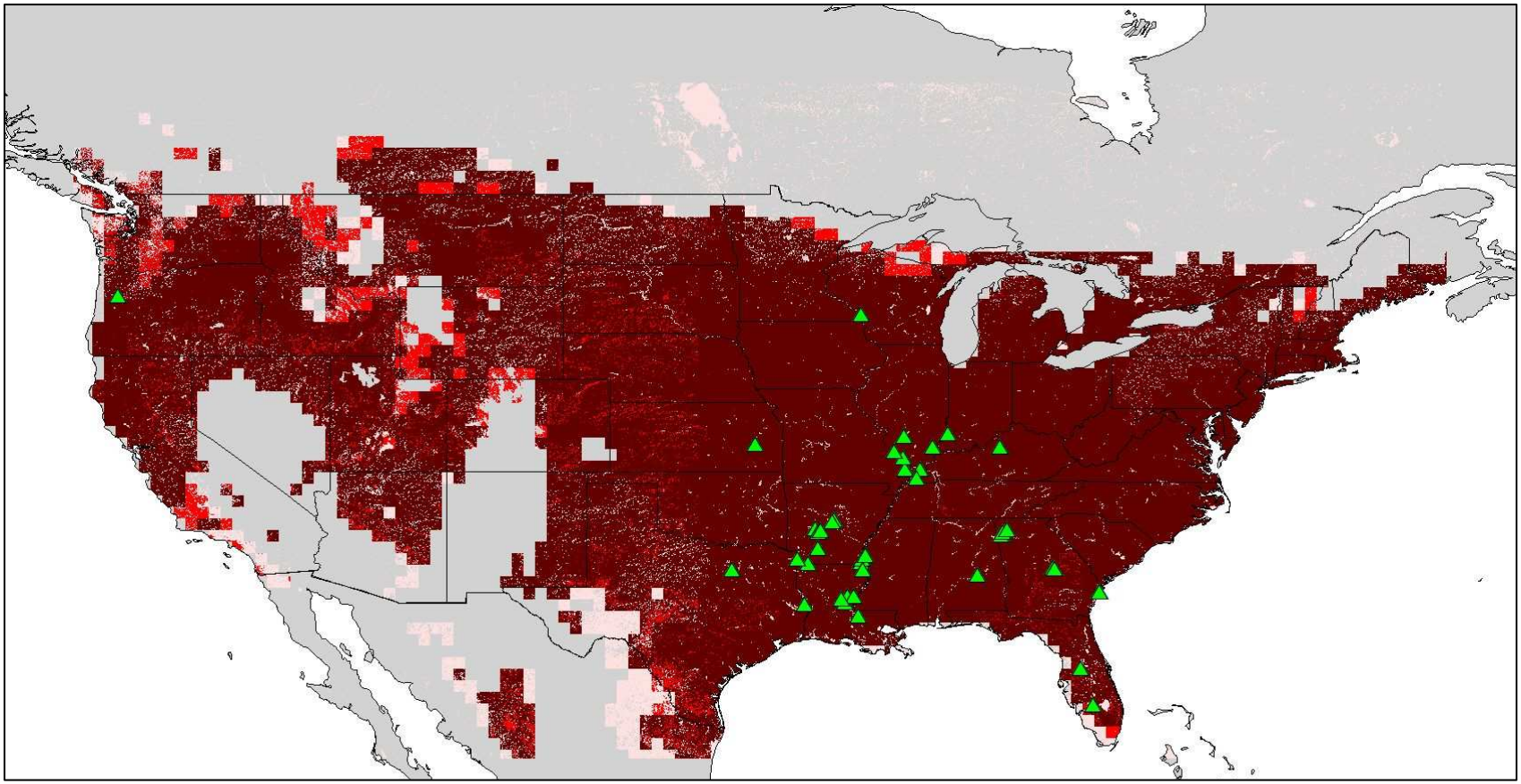
C. carpio, 170 years in NA



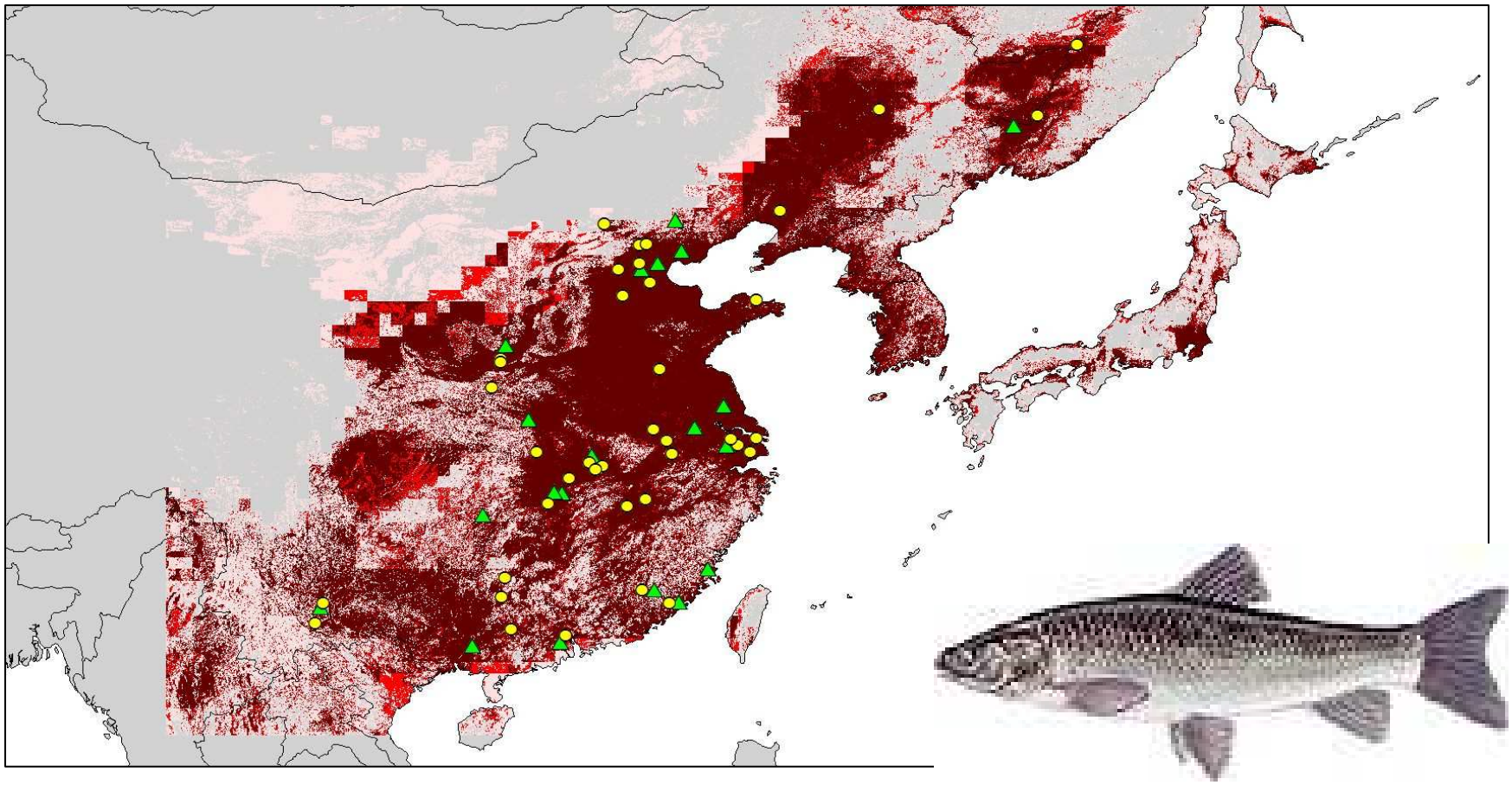
Ctenopharyngodon idella, Native Range



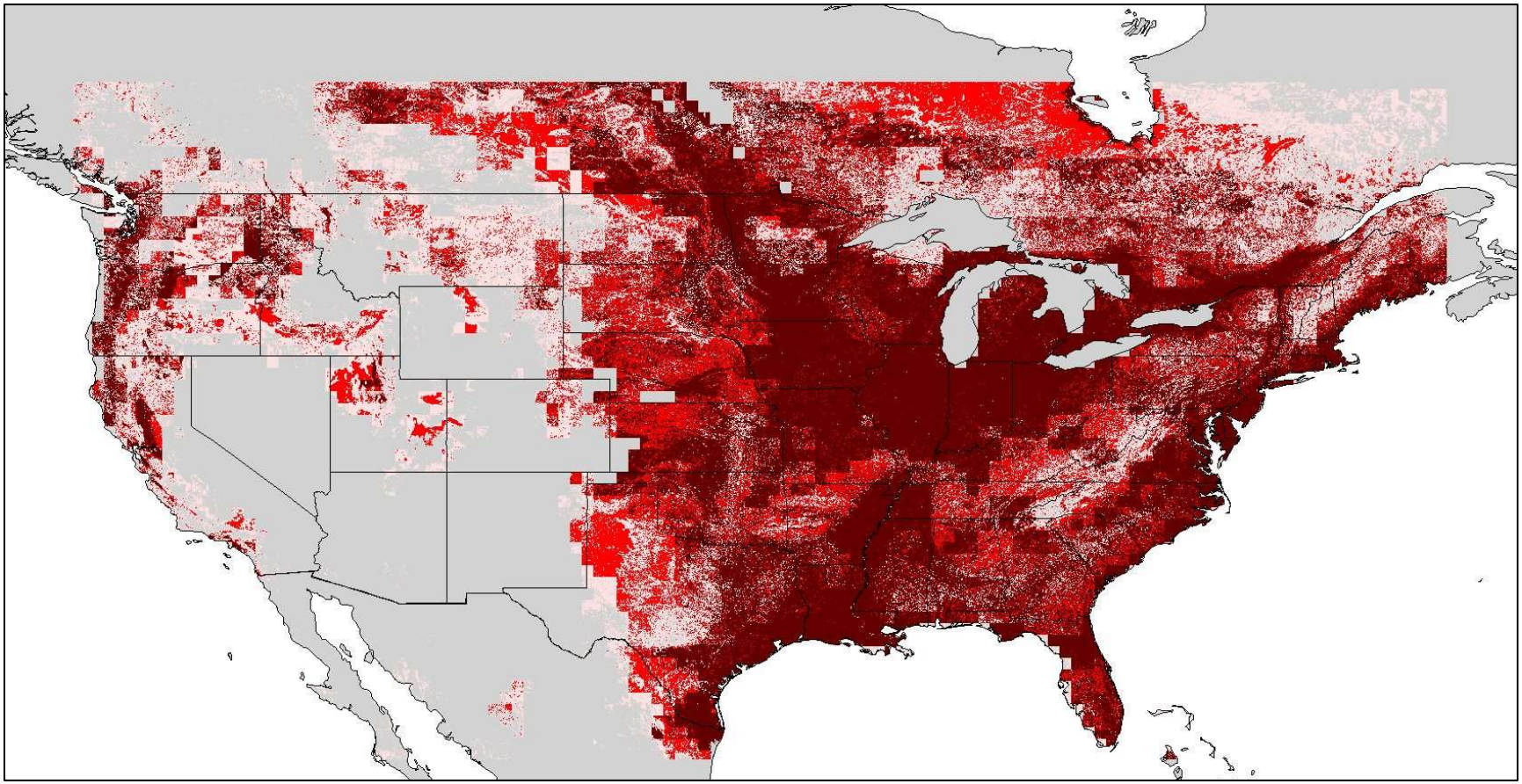
C. idella, 40 years in NA



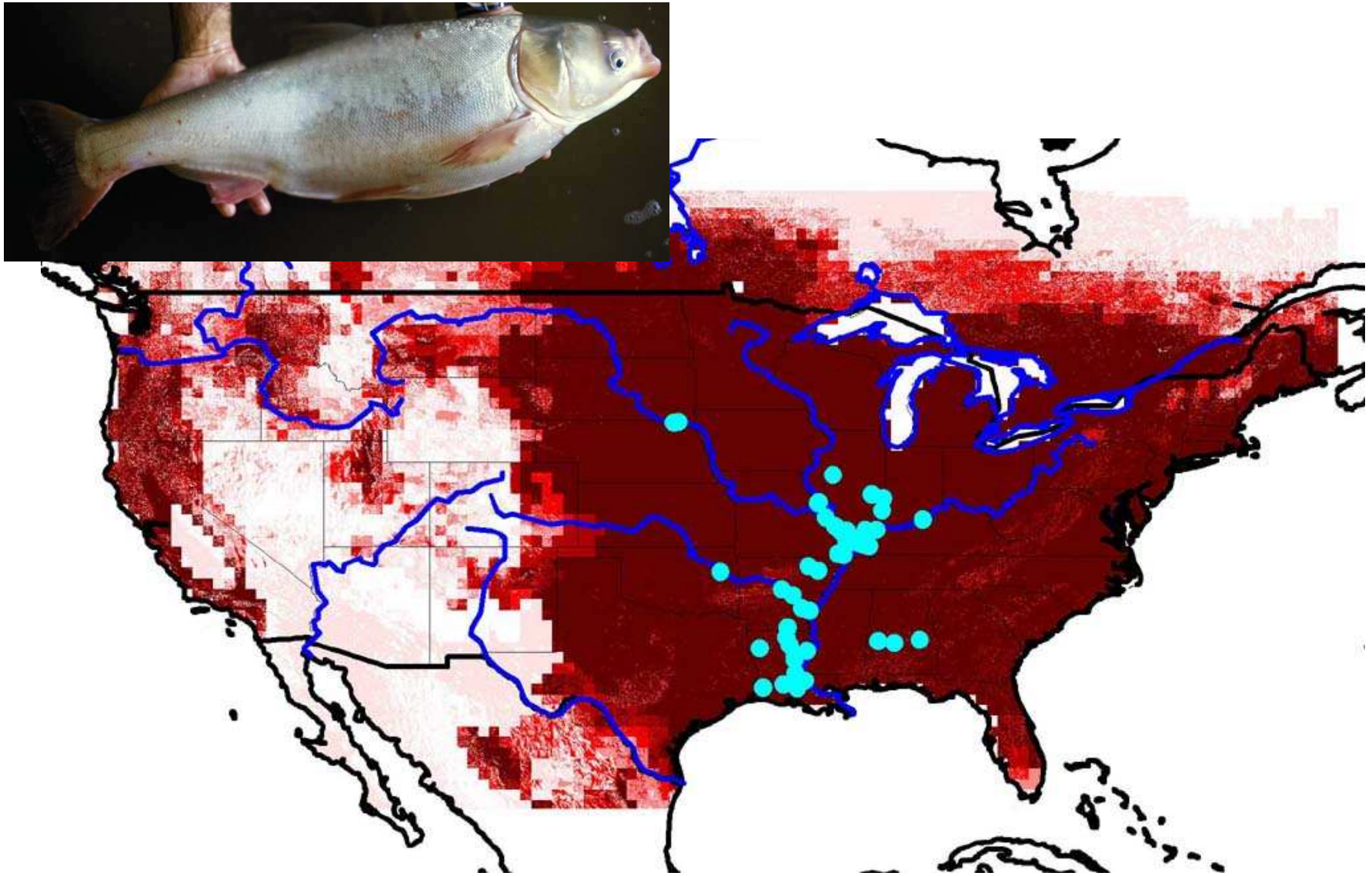
Mylopharyngodon piceus, Native Range



Mylopharyngodon piceus, new to NA



Hypothalmichthys molitrix



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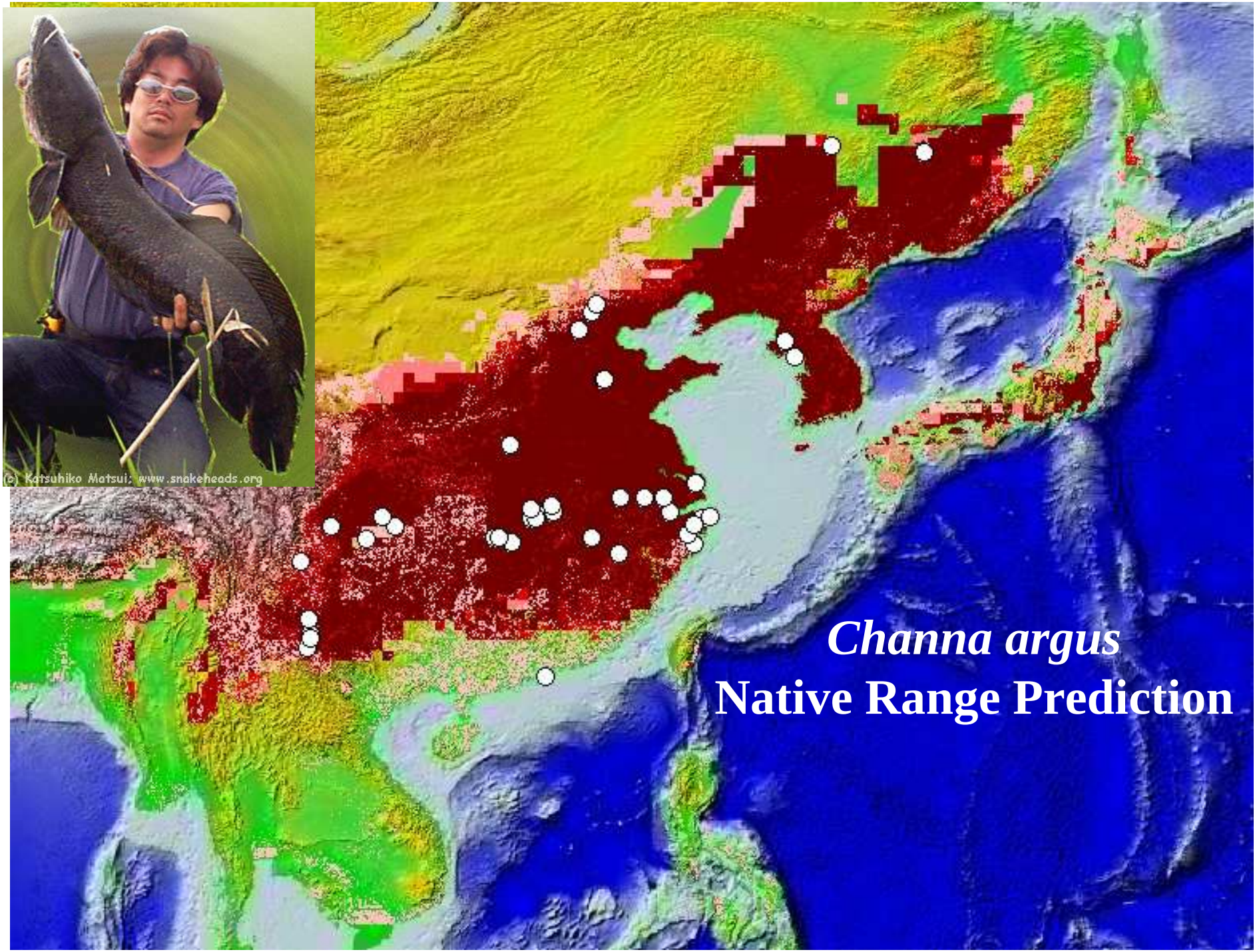
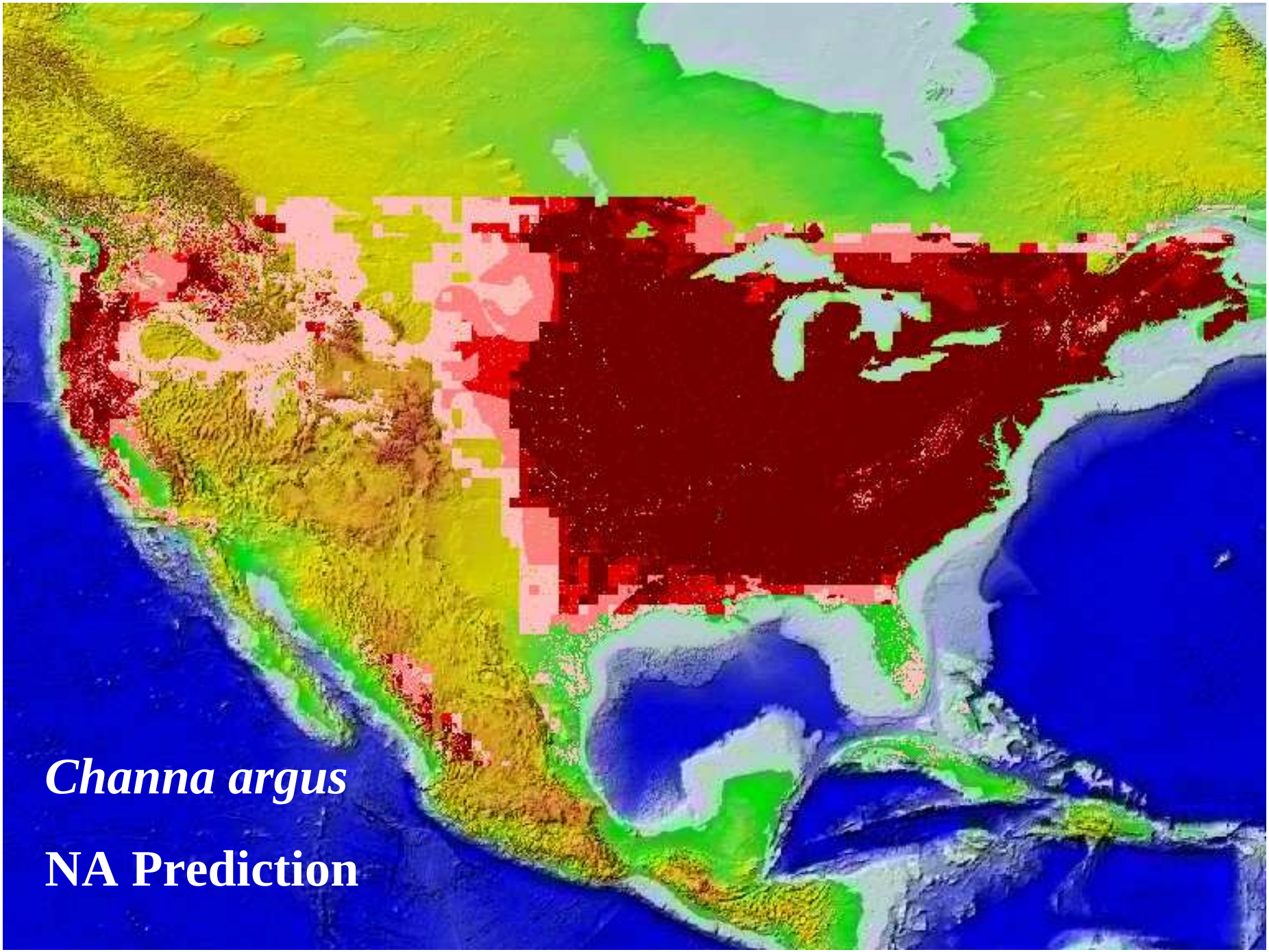

(c) Katsuhiko Matsui; www.snakeheads.org
Channa argus
Native Range Prediction


Channa argus
NA Prediction

Marine Invasives

- An outgrowth of our original marine work.
- Strategy is similar to the freshwater project.
- Players: Wiley, McNyset, Robins
- Overall strategy: Can we use remotely sensed data to supplement or even replace certain kinds of station-based data?

Did We Miss Something?

Revisit some of the original work

Monacanthus ciliatus
Station Data

ROC = 0.9535

se = 0.0029

p < 0.001

Hummmmm

- We seem to have predictive failure in some areas.
- The problem may reside in the coarse nature of the WOA data and the placement of stations in the Atlantic versus the Pacific.
- Can we find coverages that do not have this problem?
- Enter MODIS satellite data

Environmental Coverages

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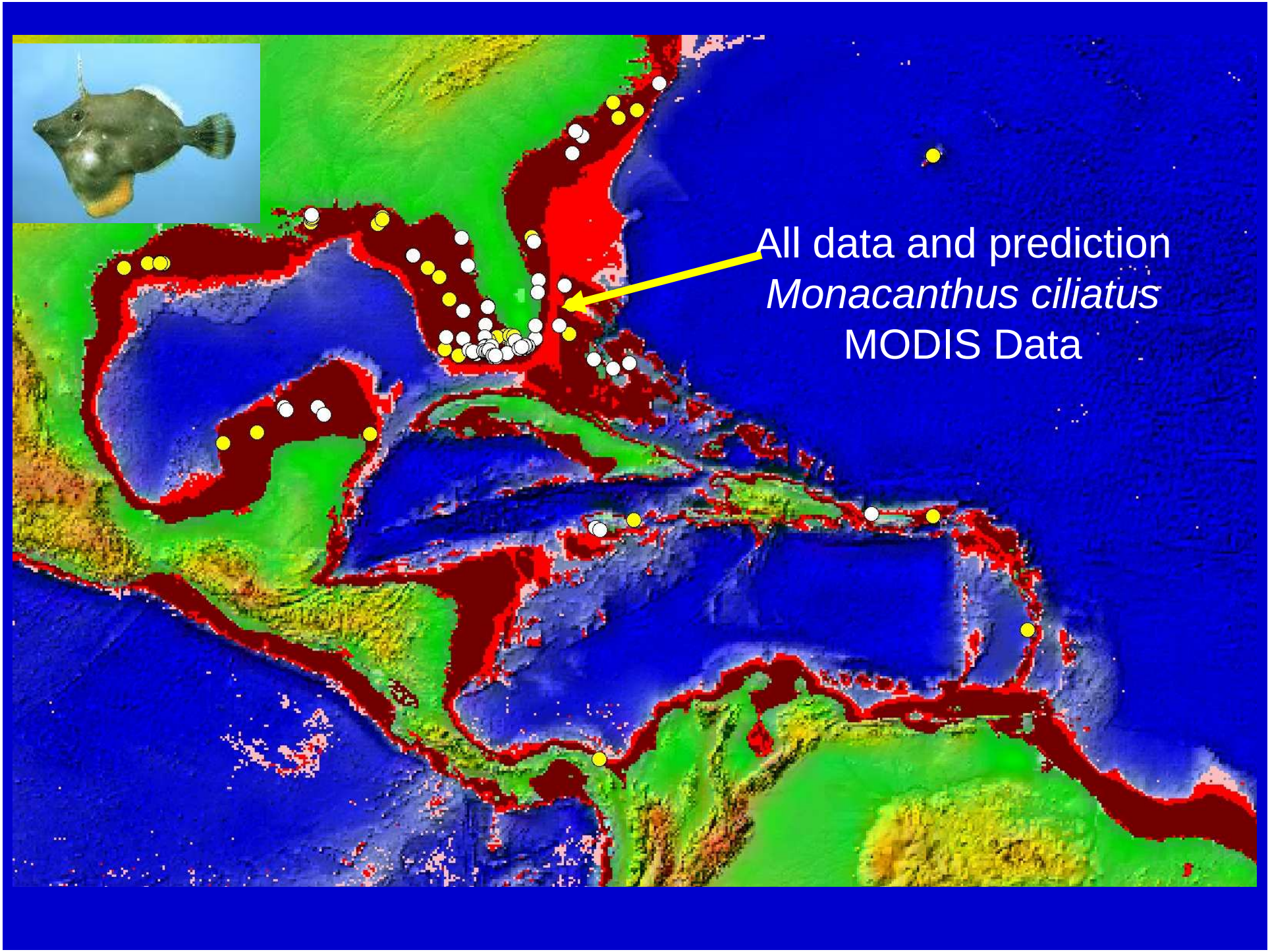
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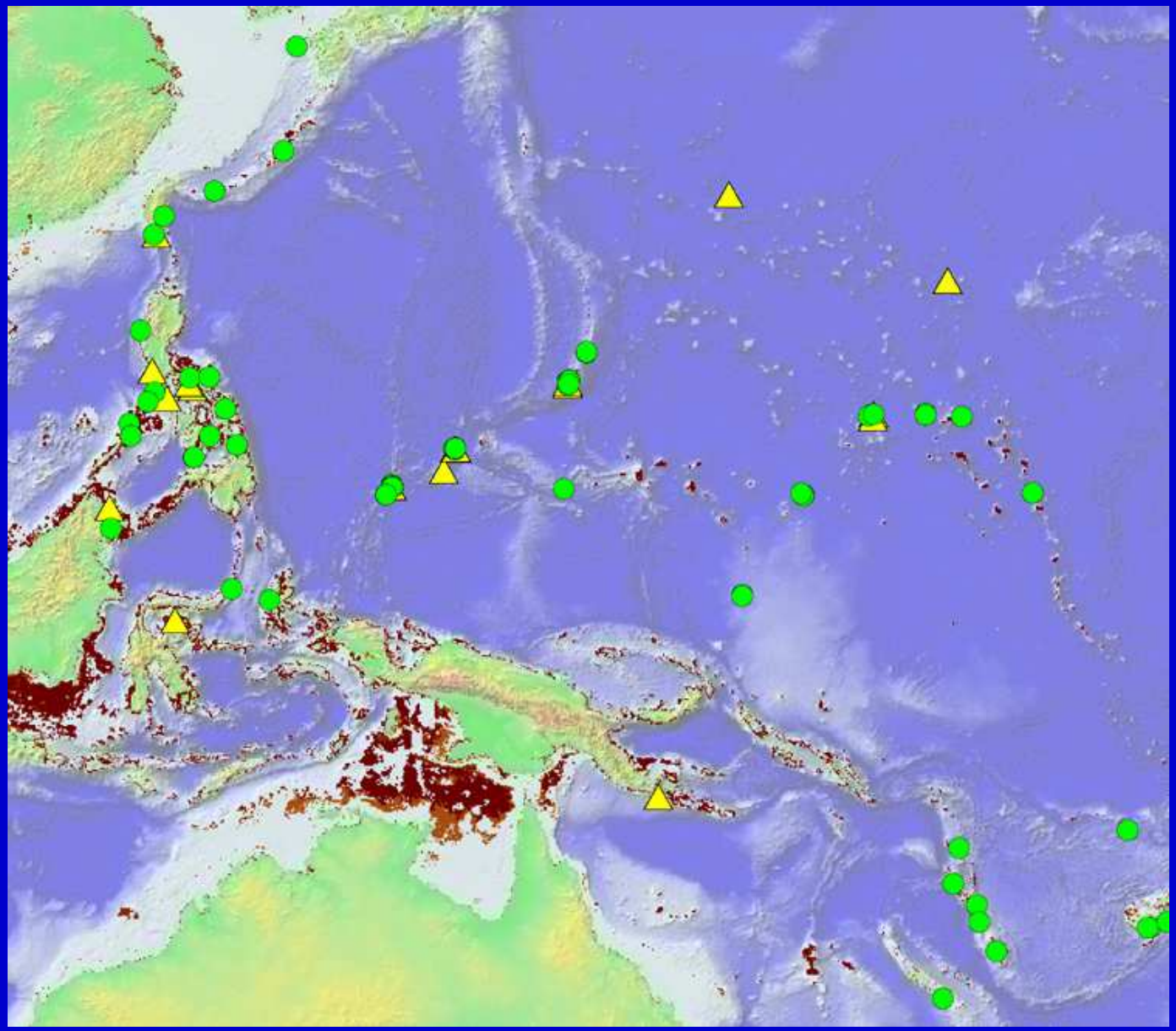
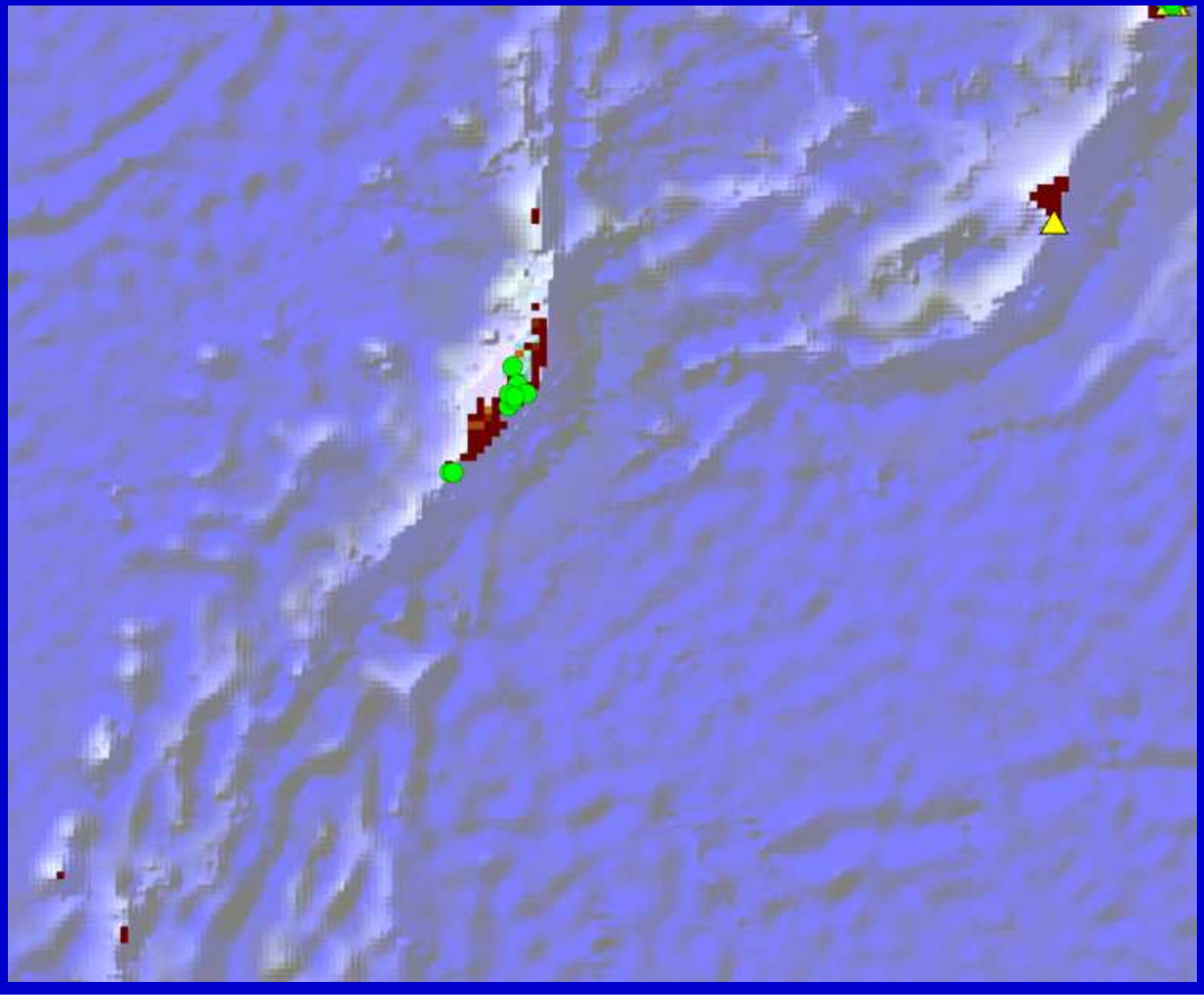
Chaetodon lunula

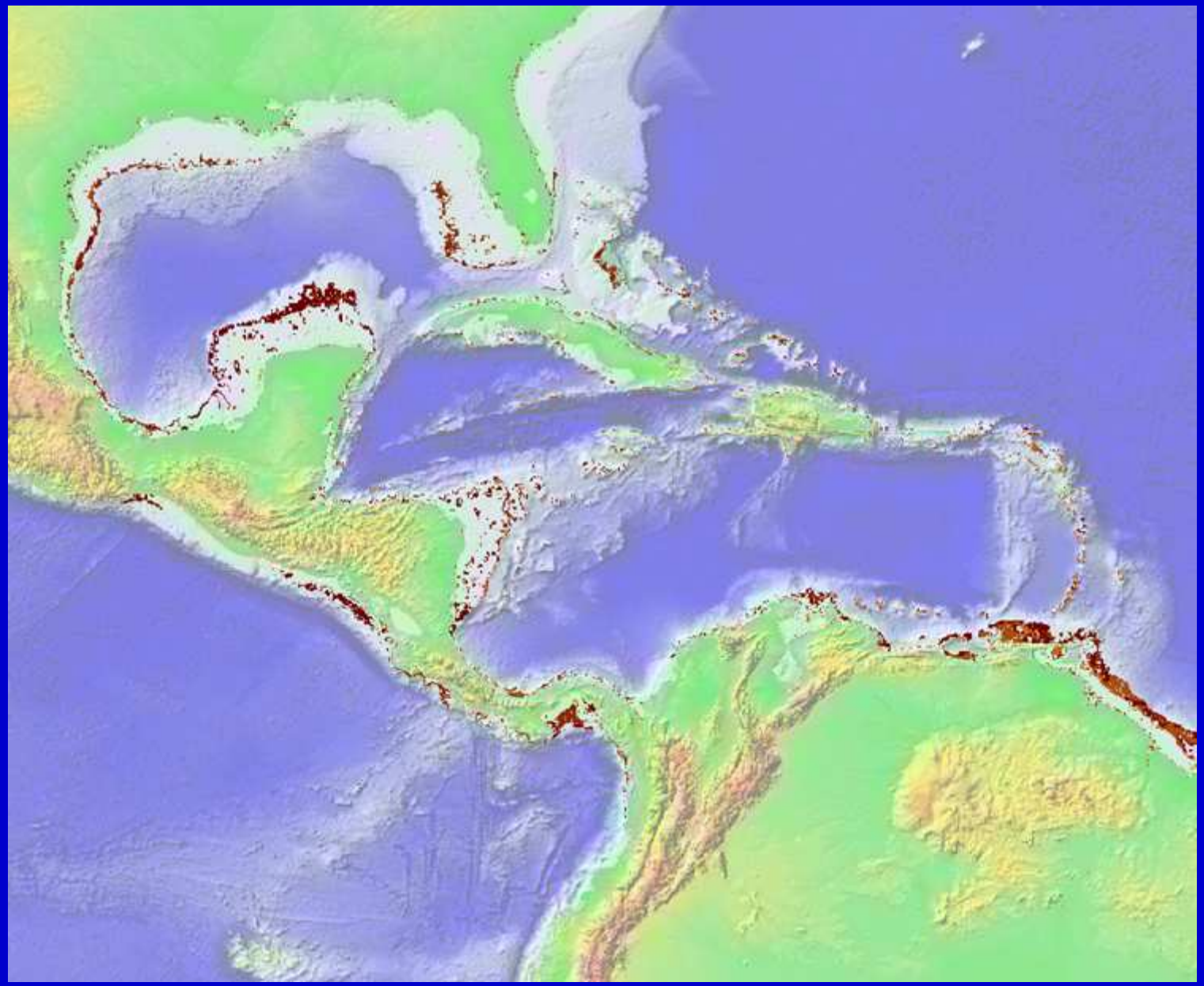
Chaetodon lunula MODIS Native Range



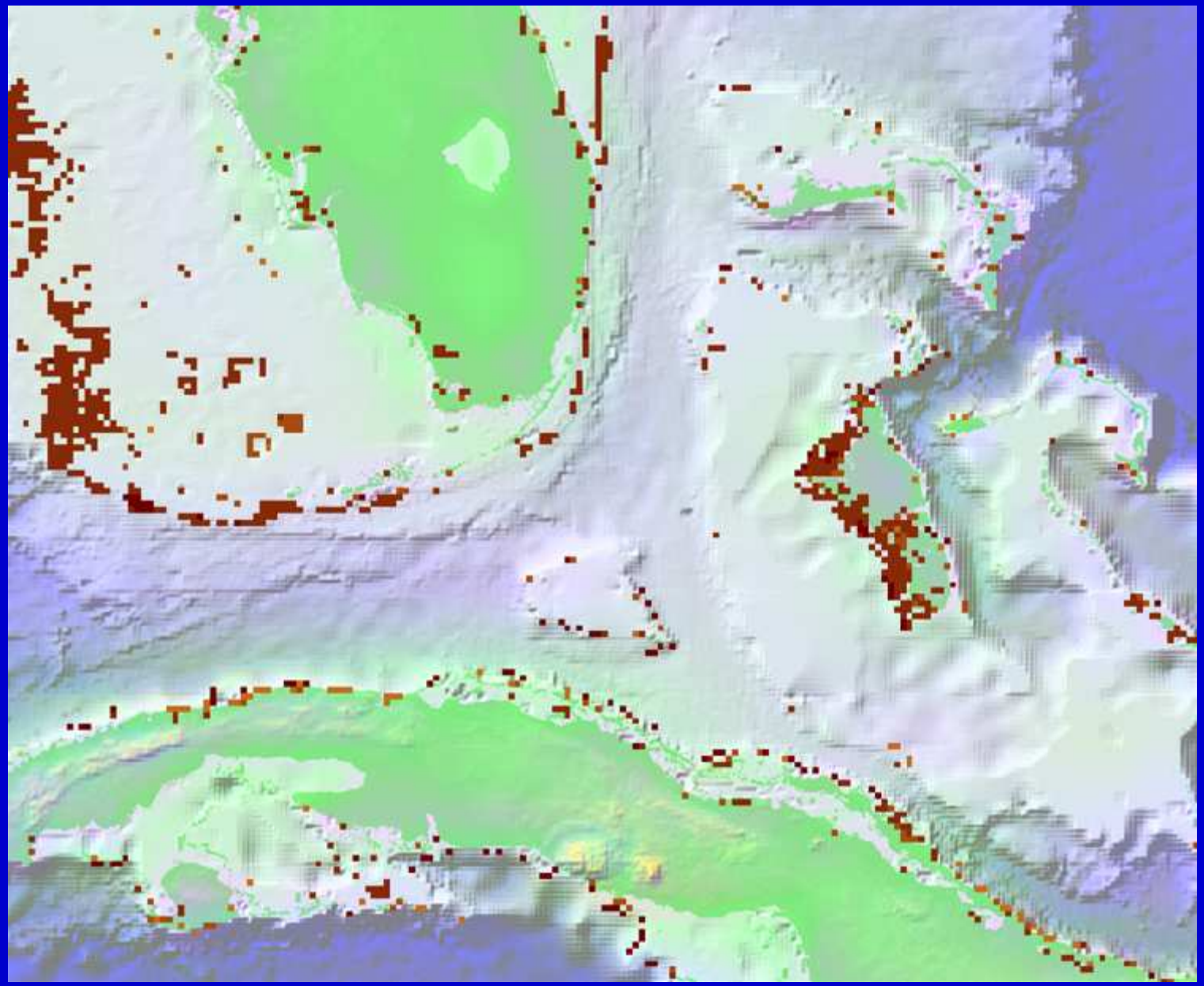
Chaetodon lunula MODIS Palau



Chaetodon lunula MODIS Atlantic



Chaetodon lunula MODIS Atlantic Details



GARP Rules

- Atomic Rules

  IF temperature = 28^{o}C & depth = 10 meters

  THEN present

- BIOCLIM Rules (Nix, 1968)

  IF temperature is 22-28^{o}C & depth 1-100 meters

  THEN present

GARP Rules

- Range Rules

Generalization of BIOCLIM rules with preconditions that must be satisfied, useful in negation and when there are environmental limitations.

- Logit

GARP implementation of logistical regression